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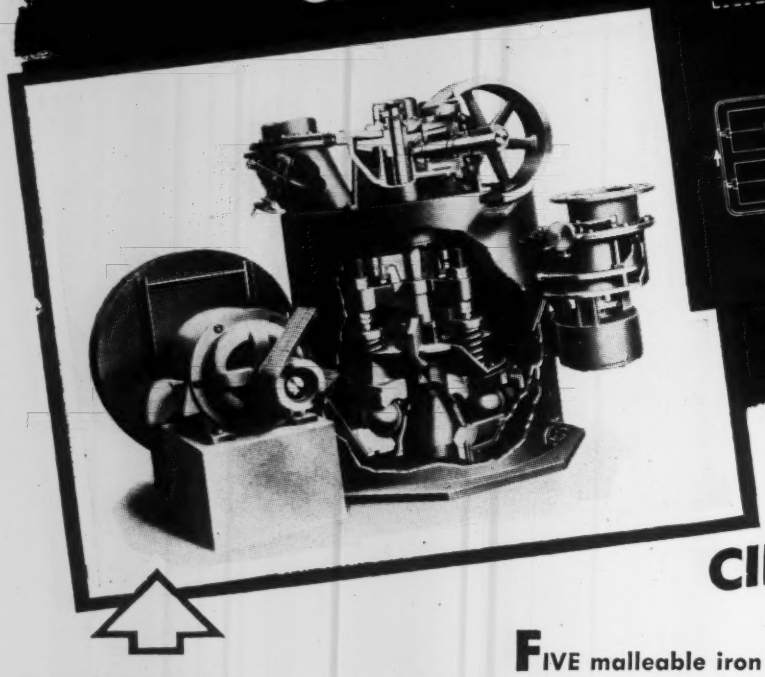
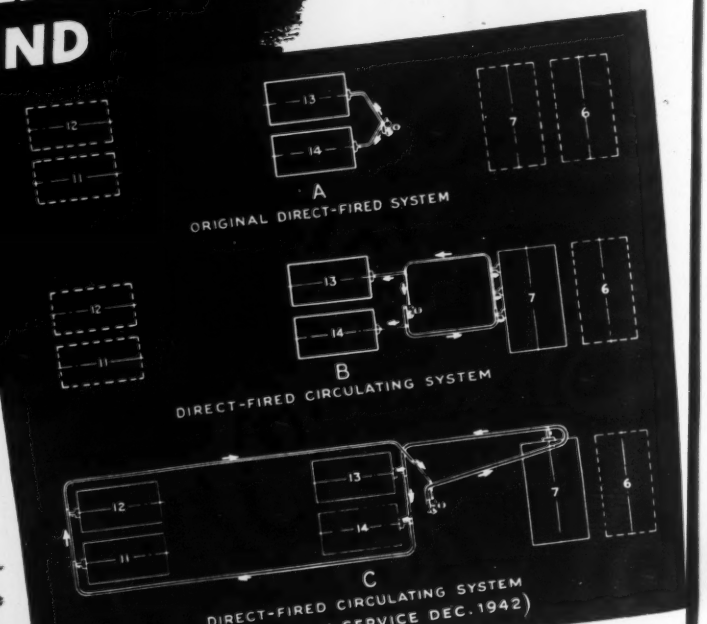
MECHANICAL ENGINEERING

JUNE 1944

PRODUCTION INCREASED, HEATING CYCLE AND FUEL COST CUT, IN ANNEALING MALLEABLE CASTINGS





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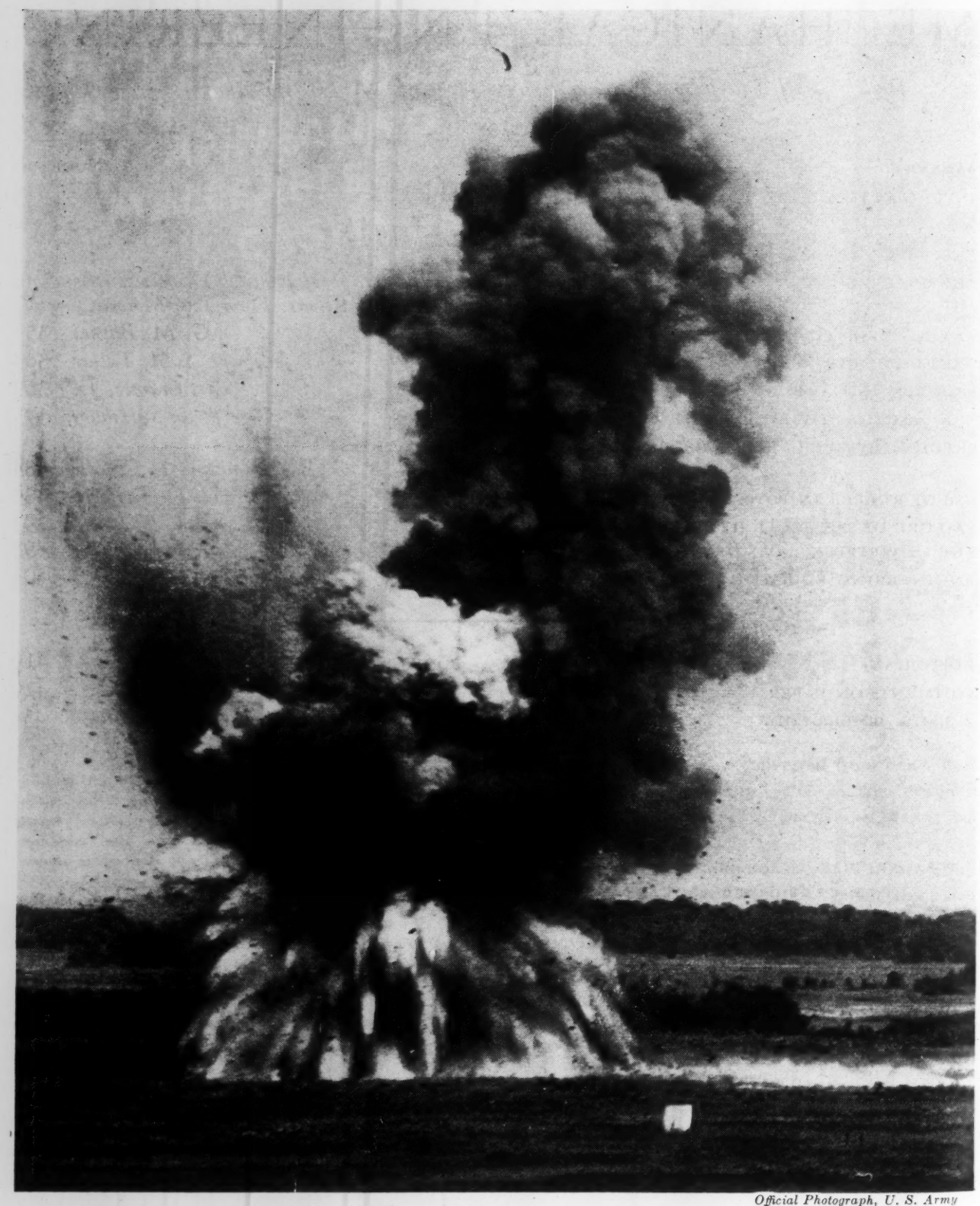


Official Photograph, U. S. Army

2000-Lb Demolition Bomb Explodes

(Detonating with an earth-shaking crash, it sends flame, smoke, and earth 2000 feet skyward. This photograph was taken with a telescopic lens from a safe vantage point a mile distant from the blast. At any point within a mile radius, the life of the photographer would have been unnecessarily endangered. For other pictures of this series see article by Major General G. M. Barnes, pages 359–362 of this issue.)

VOLUME 66
No. 6

MECHANICAL ENGINEERING

JUNE
1944

GEORGE A. STETSON, *Editor*

Manners Maketh Man

HIGH ideals and a code of ethics are all very necessary but the young man entering a business organization for the first time usually needs more specific instructions on behavior and the amenities to be observed. The bitter experiences of an unexpected rebuke, failure to make progress in friendly relations with associates, the embarrassment of finding out that good intentions, straightforwardness, or even an assumed modesty of manner are misinterpreted are more frequently the result of not knowing how to conduct oneself in a new environment than they are the consequence of natural boorishness and lack of consideration for others. One can always find out through experience and hard knocks how to behave in a bridge game, or in a shop or office. But much the pleasanter way is to be forewarned and to follow a few simple and obvious rules established by the experiences of others. It is these rules that W. J. King, in a series of three articles, calls the "unwritten laws of engineering."

The first of the series appeared in the May issue and covered what the beginner needs to know at once. But the novice in engineering organizations is not the only person who needs to read and ponder what Mr. King has to say. How the engineering executive can improve his own personnel relations is dealt with in the second of the series, published this month.

Many an executive, many an old timer who has not gone very far in an organization, may still profit by a review of these keen observations on preferred personal conduct. Sometimes the most obvious truisms need to be most frequently repeated. Such is the case of the ordinary day-by-day rules that make living and working together in organizations a pleasant and profitable experience, rather than a near tragedy. Each man who reads Mr. King's "unwritten laws" will know in his own heart how many of them he himself violates. If he is wise, he will examine his own conduct objectively and resolve, for his own sake and for the sake of his associates, to mend his ways.

Gas Turbines

TWO articles on the gas turbine, which appear in this issue, bear witness to the interest engineers are displaying in this type of prime mover and to the continued enterprise of the Oil and Gas Power Division of The American Society of Mechanical Engineers in keeping members informed of developments in its field.

The Oil and Gas Power Division, at whose Seventeenth National Oil and Gas Power Conference, Tulsa, Okla., the articles referred to were presented, has the distinction of being the first of the A.S.M.E. professional divisions. Organized in 1908, the Gas Power Section was the predecessor of the present Oil and Gas Power Division. At the organization meeting, after the business of appointing officers and committees had been accomplished, the group adjourned to the auditorium in the then new Engineering Societies Building, in New York, to listen to the presentation of a paper by Henry Harrison Suplee, "Recent French Experimental Gas Turbines," in which the designs of Armengaud and Temale, as well as the high-pressure multiple-turbine air compressor of Rateau (later an honorary member of A.S.M.E.) for use in connection with gas-turbine experiments, were illustrated. That same year F. C. Wagner presented to the Section a paper, "Some Possibilities of the Gasoline Turbine." Thus began a series of papers on the gas turbine contributed by the Oil and Gas Power Division in which important developments have been noted.

In 1924 a comprehensive theoretical study of gas-turbine cycles, of the constant-volume as well as the constant-pressure type, was presented by Marks and Danilov. Christian Lorenzen described his gas turbine and turbo-supercharger at an Oil and Gas Power session in 1930, and Adolphe Meyer, of Brown Boveri, contributed two papers, one in 1935 on the Velox steam generator in which the gas turbine is an essential feature, and one in 1939, which dealt with fundamental economies and applications of the gas turbine to power generation, ship propulsion, locomotive drive, blast-furnace blowers, and its use in stand-by plants and the process industries. The interesting possibilities of combining the supercharger with the Diesel engine were discussed by Alfred J. Büchi at a meeting in 1936 and further elaborated by F. Oderlin in 1942.

Further information on the combustion-gas turbine was communicated to the Oil and Gas Power Division by J. T. Rettaliata, of the Allis-Chalmers Mfg. Co., at the 1941 National Meeting of the Oil and Gas Power Division, and Paul R. Sidler presented a paper on the gas-turbine locomotive with electrical transmission at a joint session of the division with the Railroad Division at the 1942 A.S.M.E. Annual Meeting.

With the progress of the war, superchargers for aircraft engines became of vital importance in high-altitude flying and combat, so that the A.S.M.E. Aviation Division has been supplementing the contributions of the Oil and Gas Power Division in the field of the gas turbine. Two important papers were presented by the Aviation Division in 1943, one by R. G. Standerwick and W. J. King, of the General Electric Company, at the Los Angeles meeting, and the other, which contains an extensive bibliography, by Sanford A. Moss, at the 1943 Annual Meeting.

The foregoing survey by no means covers the entire

list of A.S.M.E. papers and published abstracts of papers on the gas turbine and related subjects, but it does serve to show the alertness of the Society to a subject which is only new because, under the stimulus of developments in metallurgy and aviation, and the accelerated progress born of military necessity, the practicability of commercial gas turbines comes day by day closer to reality. The two papers published in this issue make clear what progress is being made in this direction and discuss some of the remaining limitations yet to be overcome.

At the Tulsa meeting the Oil & Gas Power Division acted in a thoroughly practical and progressive manner by appointing a Co-Ordinating Committee on Gas Turbines under the chairmanship of R. Tom Sawyer, American Locomotive Company. Serving on this committee are: Kenneth A. Browne, Wright Aeronautical Corporation; J. R. Carlson, Westinghouse Electric & Manufacturing Co.; C. W. Good, University of Michigan; C. H. Johnson, U. S. Maritime Commission; J. T. Rettaliata, Allis-Chalmers Manufacturing Co.; J. Kenneth Salisbury, General Electric Company; Paul R. Sidler, Brown, Boveri and Company; Ronald B. Smith, Elliott Company; and S. A. Tucker, McGraw-Hill Publishing Co.

S.P.E.E. Report

EDUCATION, as A. R. Stevenson, Jr., frequently asserts, is the common concern of all of us. For teachers of engineering this concern is professional. For executives it is a continuing function which makes or mars their effectiveness in training subordinates. For all of us it is, or should be, a lifelong experience, begun in early childhood and never completely finished in the maturing, expanding, and inquiring individual. It is trite to repeat the familiar statement that the salvation of our civilization depends on education, but no other term covers as many of the factors involved.

If the foregoing assumptions are admitted, then any serious study of education conducted by competent persons should excite our interest. Such a study, recently made under the auspices of the Society for the Promotion of Engineering Education by a committee of distinguished educators and engineers, is summarized in the report, "Engineering Education After the War," published in this issue.

This report and the 1940 S.P.E.E. Report on Aims and Scope of Engineering Curricula (published in MECHANICAL ENGINEERING, October, 1940, under the title "Whither Engineering Education") provide convenient summaries of what engineering education is attempting to accomplish in this country and the philosophy of the men who are directing it. Persons seeking brief positive statements and novel ideas will find the 1944 report too long and too much an affirmation of conviction that engineering education before the war was on the right track. The report discloses no revolutionary tendency to cast the old aside and strike out along new lines for the sake of being different. The planners have refused to be swept off their feet or to embrace the usually fallacious belief that evolution exhibits startling discontinuities requiring drastic changes. If this cautious conservatism is disappointing to some who believe that the war developed new and better educational methods, the philosophical and pedagogical observations with which the report is heavily larded should serve to re-establish a sense of balance in confused minds. This is not a conviction that engineering education before the war was perfect but merely a belief that the prewar trend was in the right direction, and that improvement, as suggested by the committee, can be carried out.

Engineers in practice should be grateful to the Committee for including in many places in the report their views on engineering attitudes, professional ideals, and personal responsibilities, and for the implication that these matters will be of increasing concern to the administrators and faculties of engineering schools. Basic articles of faith, set forth in the 1940 Report and reaffirmed in the 1944 Report, attest to the educators' concern for developing men of full habit of mind—well-rounded intelligent citizens, rather than narrow specialists content to evade the larger obligations of the good citizen.

Recognition by the Committee of three broad categories of engineering students—those who will pursue the regular technical curricula; those who will train for positions as managers and operators; and (that smaller group) those who, with graduate study, enter the scientific and creative phases of engineering—is a heartening indication of the realization that differences in temperament and talent exist and can be developed to the benefit of all.

So frequently has the 1940 Report been referred to since its appearance, that little doubt of its significance should exist. The 1944 Report will bear an equal amount of attention and close study. Together the two reports constitute a handbook for educators and friends of engineering education. The professional engineering society takes up the task of education and development where the engineering school leaves off. In fact, the two types of institution have overlapping interests, as the student branches of the societies demonstrate. While each has its function and field of endeavor, common ultimate objectives demand ever closer co-operation which must be accomplished without either invading the special field of the other. As it has frequently been said, the engineering teacher has it in his power to shape the minds and habits of future generations of engineers toward greater professional consciousness and public service. Engineering societies have a stake in assisting engineering teachers in this cause which they can advance by being of even greater help in the future than in the past. And the follow-up is the obligation of the engineering society which, if it fails in its task, will be guilty of offering the hollow shell of futility and frustration to men who expect the solid substance of opportunity for progress and service to society through a purposeful and objective professionalism that is a challenge to the best efforts of men with superior training.

But to return to the report itself. It is divided into preamble and two parts, the first devoted to the purposes and problems of engineering education and the second to matters of immediate concern. If the busy reader wishes to familiarize himself with the substance of the report, he may read the preamble and the conclusion of each section (pages 403 and 412). Then, undoubtedly, he will wish to read the entire report.

Signal Corps Photograph

MANEUVERS IN HAWAII; IN ACTION WITH 105-MM HOWITZER

KEYING RESEARCH *to* BATTLE

By MAJOR GENERAL G. M. BARNES, U. S. ARMY

CHIEF, TECHNICAL DIVISION, OFFICE OF CHIEF OF ORDNANCE, WASHINGTON, D. C.

THE war has proved the value of research and development work carried out by the Ordnance Department prior to 1939 with limited funds. Our country was saved in this present situation through the existence of a nucleus of experienced Ordnance officers, engineers, and key personnel, its long-established proving grounds and manufacturing arsenals, as research centers, coupled with the greatest industrial system in the world. While Ordnance lacked adequate development funds, many scientists, engineers, and commercial organizations contributed patriotically in helping to solve these military problems.

As soon as the war started in Europe, by the German invasion of Poland, the Department redoubled its efforts to accelerate the development of critical weapons and to complete the detailed drawings and specifications.

Fortunately, Congress appropriated a large sum of money for munitions, and in September, 1940, $1\frac{1}{4}$ billion dollars became available for the purchase of ordnance weapons. It is a matter of record that within two weeks the department was able to spread its orders over the whole country and to tell industry "what was wanted" through the medium of detailed drawings and specifications for each item of ordnance, together with the quantities required.

ORDNANCE DEPARTMENT RESPONSIBILITIES

But first, it might be well to state the scope of the responsibilities of the Ordnance Department in regard to fighting weapons. These responsibilities include all weapons used by the Army and many for the Navy and Marine Corps. Included in this long list of more than 2000 principal items and about 500,000 components are all the weapons used by the infantryman—rifles, machine guns, ammunition, grenades, mortars; those required to put the sting into the airplane—bombs, machine guns, automatic cannon and ammunition; the weapons of the Field Artilleryman—from the 105-mm howitzer, the backbone of the Field Artillery in this war, through the various calibers—to the great 240-mm howitzer or 8-in. mobile gun; all calibers of antiaircraft guns, fire control, and ammunition; the various types of tanks, armored fighting vehicles, and motor transportation for the whole Army. This was the field covered by Ordnance in its research and development programs in peace with meager appropriations of about $1\frac{1}{2}$ million dollars per year.

An important phase of this prewar planning was the establishment of 13 Procurement Districts in 1918. Although each District Headquarters at first consisted only of 1 regular officer and a secretary, nevertheless, by working with industry over a 20-year period, a thorough survey was made and those manufacturers best qualified for the manufacture of various types of munitions were selected and given tentative production orders. When the emergency arose, 84 per cent of these manufacturers accepted and signed contracts with the Ordnance Department.

INDUSTRY PROMPT AND VIGOROUS

The next problem was to teach manufacturers of commercial goods how to meet the Army's rigid requirements for manufacturing weapons and explosives. In this task the arsenals, each covering a part of the Ordnance field, made a great and lasting contribution. Manufacturers freely used the arsenals and were given all the technical information which we possessed concerning each item. In addition, engineering committees were formed; one committee for each class of ordnance material. Thus, there was a committee on shell forgings and another for antiaircraft carriages, some 25 in all. These committees met once or twice a month to discuss engineering problems encountered and to propose changes in drawings and specifications. A system for approving, within 24 hours, changes in drawings and specifications was inaugurated under the supervision of the manufacturing arsenals. American industries undertook this work with vigor and were able to get into production on all essential weapons in an amazingly short time. Our capacity for munitions thus built up has been so great as to enable this country to supply its own Armies and very largely the armies of our Allies. This might be considered phase I or the beginning of the munitions effort in this war.

NEW WEAPONS

Under phase II the problem of developing new weapons to fill gaps in the equipment required by our Armies and our Allies

An address delivered at the Banquet held in connection with the 1944 Spring Meeting, Birmingham, Ala., Apr. 3–5, 1944, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

might be included. Due to the prewar shortage of funds, the Ordnance Department had not been able to develop all needed types of weapons. This was especially true of the more expensive weapons, such as heavy artillery. An intensive program also was started which contemplated the final replacement of every existing type of weapon and ammunition with articles of superior design as soon as possible, and the development of new and hitherto unknown weapons. Phase II did not start upon the completion of phase I, but ran concurrently with it. An intensive study of enemy weapons was inaugurated in order that a basis of comparison might be established and, furthermore, that any usable ideas could be seized upon and turned to our advantage. In order to obtain this information, a special organization was set up in the Technical Division, Office of the Chief of Ordnance, under which selected officers were trained. After training, these officers were dispatched to the various theaters where our troops were in contact with the enemy. Their mission was to secure all types of enemy weapons and see that they were transported to the United States in the quickest possible manner.

For example, during the advance of the British Eighth Army toward Tunisia, when the German 88-mm antitank gun came into prominence, one of these guns was flown from Africa to the Aberdeen Proving Ground for study and trial. Our technical intelligence Ordnance officers have been so successful in this work, both in the Pacific and in the European Theaters, that we now possess practically every known type of enemy weapon. We have, at the proving ground, more than 4000 tons of these weapons and ammunition of all types and description, which have been sorted out, classified, and studied. Firing tests, for example, of German artillery are being made in comparison with our own. With firsthand knowledge of enemy weapons, we have been able to keep well ahead of German and Japanese weapons. We have made full use of the greatest military asset of this country—our engineering and industrial strength. Today, a great part of our weapons of current manufacture were designed and developed in 1940. Subsequently, we know that a large part of the German weapons were designed in the late '20's and early '30's. However, it would be a mistake to give you the impression that the Germans are not doing their best to produce new weapons in nearly every category.

WEAPONS FOR SPECIAL NEEDS

I have considered phase III as covering the current situation in which we now find ourselves in so far as the development of new weapons is concerned. While research and development under phase II are still continuing, we have entered this new phase, which involves the development of special weapons required by our troops to meet special situations. In this war, ordnance must function equally well at the Arctic Circle or in the dank jungles of New Guinea. Special weapons help in unusual tactical situations found in amphibious, mountain warfare or in the establishment of a beachhead by an invading force. There are many new and outstanding ordnance weapons which have been used effectively in various theaters making it possible to release limited information concerning them. Some of these weapons have been described in current publications but their true significance has not always been adequately evaluated.

RIFLES SUPERIOR

No general statement of Ordnance would be complete without at least a brief reference to the M1 rifle, which was standard from the beginning of the war. This has been of outstanding importance because it is the weapon of each fighting soldier. In the American Army, the rifle and marksmanship have always been considered of first importance. It is indeed fortunate that the M1 rifle was ready for production. Although tremendous engineering and tooling problems were involved in the mass production of the M1 rifle, these were satisfactorily solved so that now more than 1000 of these rifles are made daily by Springfield Armory alone. The characteristic which makes this weapon of such outstanding importance is the fact that one American soldier with the Garand rifle is equal in fire power to two soldiers of any other nation armed with bolt-action rifles. It has been proved time and time again that expert riflemen or laymen can fire the M1 rifle at approximately $2\frac{1}{2}$ times the rate of the ordinary military rifle.

Fortunately for us, no other nation can copy this rifle in this war and produce it in quantity. The Germans already have undertaken to do this and have attempted to build a competing shoulder rifle and a few have appeared on the battlefield. Again, fortunately, these enemy rifles are of indifferent manufacture and quality. While the M1 rifle has been captured by our enemies, due to the engineering and manufacturing problems involved, there is nothing they can do which will make it possible for them at this late date to come abreast of this weapon.

"RESULTS SPEAK FOR THEMSELVES"

In the field of aircraft armament, the caliber-.50 aircraft machine gun stands by itself. Here, again, we have the example of a weapon which was developed over a period of 20 years jointly by the Ordnance Department and the Colt Patent Fire Arms Manufacturing Company, which was available for mass production from the first. It is not only the machine gun which is exceptional, but also its highly developed ammunition. This special ammunition was developed at the small-arms plant at Frankford Arsenal. In this war the Germans and the Japanese have concentrated on the 20-mm aircraft cannon for their fighter planes. Many thought the United States had made a mistake in its lighter caliber-.50 aircraft machine gun. The results of combat speak for themselves. Size or caliber is not always a true measure of effectiveness.

AIRCRAFT CANNON

Our American aviators have confidence in their caliber-.50 machine gun and know that when enemy planes cross their sights these planes will be brought down in flames. The potential value of the 20-mm-caliber aircraft gun used by both the Germans and the Japanese has not been overlooked. Their weapons are defective due to low velocities and inferior ammunition. The latest American 20-mm aircraft cannon and ammunition represent great advances over foreign types and this caliber weapon may well assume an important role in American planes in the future. Throughout the war, this country has been a leader in the development of aircraft cannon. Today, many American planes are armed with the powerful 37-mm full-automatic cannon and armor-piercing ammunition capable of penetrating the plates of German tanks. The 37-mm aircraft cannon has been especially valuable in the attack of enemy shipping.

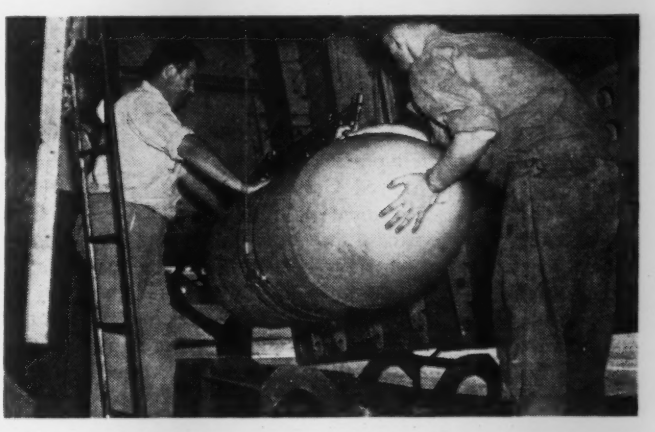
A short time ago the War Department released information concerning the Ordnance Department's aircraft weapon—the 75-mm aircraft cannon. This gun had been under development in the Ordnance Department over a six-year period. The first attempts were made by mounting a 75-mm gun of the field-gun type in an old airplane. After obtaining the necessary engineering information, this gun was finally fired from the plane in flight. From this beginning, special guns and recoil mechanisms have been designed and manufactured by the Ordnance Department so that today the 75-mm high-powered gun has become an important aircraft weapon.

An American aviator recently had a field day in the Pacific area with one such weapon. Flying over a broad area he successfully sank a destroyer, knocked out an antiaircraft battery, set an ammunition dump on fire, chased a plane in the air and destroyed it as it landed on an airfield. Whenever this enthusiastic officer missed his target he said in his report that he had "buck fever" and that it was his fault for missing. The

2000-lb demolition bombs being readied by muscular civilian expert and tested at Proving Ground. The workman is attaching tail fins to one bomb across which lies a red flag, a warning signal for other workmen to keep at a distance. Fins are placed on large bombs just prior to dropping to guide them on their flight. Of comparatively light metal, they might be bent if shipped attached to bombs. Bent fins would cause misses. In background are small bombs ready for testing.

This is the crater dug out instantly by the detonation of the 2000-lb demolition bomb after it was dropped high above the Proving Ground. The officer standing at the base of the crater is holding a still-hot fragment of the huge bomb. One-ton bombs were first developed by the Army Ordnance Department more than twenty years ago. The Germans, who should know, call them "Block Destroyers" for when they let go, the one-tonners have demolished full city blocks in German towns.

Trundled carefully on a three-wheeled pneumatic-tired carrier, the 2000-lb demolition bomb is hauled to bi-motored bomber, which will drop the huge bomb on the testing area. Notice the pistol worn by soldier who is pushing the handcart. He is armed to enforce, if necessary, rigid safety restrictions applying when high explosives are being handled.



Electric winch within bombardment plane lifts the 2000-lb demolition bomb through the bomb bay to its position in the plane, preparatory to tests, which are conducted in co-operation with the Air Corps who furnish the bombardment aircraft and flying personnel. The Ordnance Department supplies the Army Air Forces with bombs of all types and sizes.

Official U. S. Army Photos

These two ugly jagged fragments of metal held by an Army officer formed part of the case of a 2000-lb demolition bomb dropped in the test. The bombs depend for power more upon their enormous blast effect than flying fragments, which are secondary in production of damage in the case of this type of bomb.

First Actual Photographs of Dropping and Exploding 2000-Lb Bomb

(These pictures, taken recently at the Army Ordnance Department Proving Ground, Aberdeen, Md., illustrate the steps taken in preparing for loading the bombs aboard plane, adjusting fins, the bomb's being dropped from plane (see cover photograph), the actual explosion (see frontispiece), the resultant crater caused after the "hit," and fragments of the bomb picked up later near the scene.)

role of the 75-mm aircraft gun, or flying artillery, is yet to be recorded in this war.

AMERICAN BAZOOKAS

An Ordnance weapon which has been featured in the press is the "American Bazooka." The objective was to make it possible for the Infantry soldier to carry a light weapon which could be used to destroy the heaviest enemy tank. It is a matter of record that this objective has been achieved and that the Bazooka has accounted for a considerable number of the 67-ton German Mark VI "Tiger" tanks. This, however, has been but one use which our soldiers have found for the Bazooka. It has been a potent weapon for destroying machine-gun nests; for dislodging enemy troops in house-to-house fighting; and for the destruction of Japanese pillboxes.

BEST MOBILE ARTILLERY

The American Army is now equipped with the best and most complete system of mobile artillery possessed by any army in this war. The principal weapon of the division is the 105-mm howitzer. In the last war the famous French 75-mm field gun fulfilled this role. Thousands of these highly versatile 105-mm howitzers are on all fighting fronts and the weapon is considered as the backbone of American artillery. These howitzers have not only been mounted on field-gun carriages, but also in the medium tank chassis, as the M7, or known to the British as the "Priests." A number of the Priests were sent to General Montgomery and were used by him at El Alamein and in the pursuit of the German army across North Africa. The British were very high in their praise of this weapon, stating that in many cases they destroyed German tanks at ranges of 8000 yards. This is the weapon which has helped to batter down the German and Japanese prepared positions in the many American attacks which have been made up to date. In the recent attack on Kwajalein 105-mm howitzers landed in the early stages of the attack fired incessantly, laying down such a complete barrage that, combined with the fire of naval guns, practically everything was destroyed on the island, including Japanese artillery positions. The firing was so intensive night and day that each 105-mm howitzer delivered 1200 rounds during the incessant bombardment.

HOWITZER FIRE DEVASTATING

A weapon which has not been talked about very much, but which is an outstanding artillery piece, is the 155-mm howitzer. The heavy shell which this howitzer throws to a range of about 10 miles is very devastating. These howitzers have likewise replaced all of the 155-mm howitzers of older models, with which we started the war. Another important weapon in the same weight class is the long-range $4^1/_2$-in. gun, which is used by the Corps Artillery for counter battery and harassing fire. The 155-mm gun, known affectionately as the "Long Tom," was the one which helped in a large measure to bring the war in Tunisia to an end. This was the first German introduction to this weapon and they were amazed at its range and accuracy. The companion piece to the 155-mm gun is the 8-in. howitzer, which has similar characteristics but throws a much heavier shell.

The Germans are now being introduced and will be continued to be introduced throughout the remainder of the war to new American long-range pieces of artillery of great power. The newspapers have emphasized the range of the German 170-mm gun. We have this weapon at Aberdeen Proving Ground and find it of excellent construction. It is, however, outranged by the American 8-in. mobile gun to the extent of some 2 miles. Our 8-in. gun also throws a projectile weighing nearly twice as much. Our great 240-mm howitzer is a weapon of great range and accuracy.

EFFECTIVE BOMBS

We hear a great deal these days on the subject of bombs, but to many a bomb is simply a steel container which is thrown overboard from a plane. In some countries today bombing is still in that category. American bombs, however, have all been very carefully designed, as have our projectiles, for ballistic performance. The design starts by placing a model of the new bomb in the wind tunnel to study its aerodynamic properties. After obtaining the necessary streamlining and balance, the bombs are next dropped from various altitudes under the eyes of ballistic cameras which record their movement through the sky. Aberdeen Proving Ground, where these ballistic measurements are made, prepares the ballistic tables used for the graduation of the precision bombing sights. When bombs were first employed, the altitudes at which planes could carry them were decidedly limited. It was found, when the velocity of the bomb exceeded that of sound, that considerable redesign of our bombs was necessary and they are now capable of being dropped from the highest altitudes. We have ascertained from German bombing in England and Africa that the Germans have a very high percentage of duds with their aerial bombs, as high as 20 per cent. This is a very poor performance compared with American bombs and bomb fuses. The Ordnance Department has designed bombs of great sizes and can furnish accurate bombs to the Air Corps of any size desired. Except for very special missions, bombs up to and including the 2000 lb are preferred, since the greater effect is obtained by several bombs rather than by one bomb of great size and weight.

Today, many types of bomb fuses are required to burst the bomb in the air, on the ground, under the ground, and at different times. The following message was recently received by the Chief of Ordnance concerning one such type of bomb fuse. I quote, "One of our 500-lb bombs fused with a 2-hr-delay fuse was dug up by our Oriental enemies and their population was decreased by a total of 75. Words of such success with this type of fuse make it more popular with us over here than ever."

While the guns are used to propel the projectile, it is the projectile which kills the enemy or produces the necessary destructive effects. The design of the artillery projectile is therefore of great importance. This is a complicated subject in that today so many different types of ammunition are required for so many different purposes. For example, our field guns are supplied with so-called "high explosive ammunition." This is a relatively thin-walled projectile carrying a large explosive charge. Accurate fuses must be made for this ammunition so that the shell will explode immediately upon touching the ground and the fragments will have good dispersion to reach targets distant from the point of burst. However, if it is desired to attack an underground installation, or to destroy resistant targets, fuses must be provided which will give the proper delay to permit the projectile to enter the target before it bursts. For the 105-mm howitzer about some ten types of ammunition are required to meet all the special needs of the artillery troops.

BODY ARMAMENT FOR AVIATORS

A new development in this war has been the use of body armor by aviators. In the last war German infantry troops used body armor to a certain extent and our troops were likewise supplied with body armor for the stabilized trench warfare which existed at that time. More recently, thousands of suits of a new type of body armor have been issued generally throughout the services to our aviators. The following is an official report concerning its use: "Reports from the Eighth Air Force indicate that up to December 1, 1943, 1937 incidents have occurred in which individuals wearing body armor were struck by enemy missiles. Of these, 21 were saved from severe injuries, although the armored suits were seriously damaged. Three individuals were killed by fragments which penetrated the armor."

These are examples of how American lives are saved by "Keying Research to Battle."

GAS TURBINES

Present Status and Future Prospects

By S. A. TUCKER

ASSOCIATE EDITOR OF "POWER." JUNIOR A.S.M.E.

As lately as 1936 the supercharged furnace of a Brown Boveri Velox boiler was equipped with the first gas-turbine axial-compressor charging set that produced a net power output from exhaust flue gas in excess of the amount required for compressing combustion air. Prior to this time the Holzwarth explosion turbine and the quasi-experimental 100-hp machine of Jendrassik (the only devices then capable of producing a net power output) offered little ground for optimism as to the future of any gas-turbine power unit. Experience in construction of these and earlier units, however, contributed a great deal to the design and construction of present continuous-combustion machines.

As the situation now stands, the center of interest for power, propulsion, and process application is the continuous-combustion cycle represented by the gas-turbine axial-compressor unit developed by Brown Boveri and Allis-Chalmers. These differ materially from any type of Diesel or gasoline-engine turbosupercharger in that they employ, usually, a multistage compressor and produce useful mechanical or electrical power directly or as a by-product.

While "application" engineering of the gas turbine has hardly begun, there are many indications that the continuous-combustion compressor-turbine cycle is destined to play an important part in transport by land, sea, and air. The gas turbine has potentialities for power generation and supply of process steam or air far beyond ordinary competition with the steam turbine and Diesel engine.

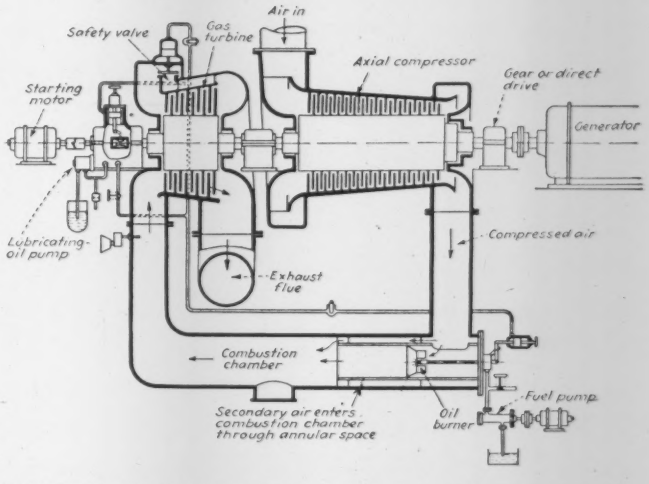
Basic equipment for a gas-turbine prime mover includes, usually on a single shaft, the turbine itself, a high-efficiency compressor, some means of starting, and a generator or other means of power take-off. A combustion chamber, limited for the present at least to oil or gas firing, provides for burning fuel at very high heat-release rates under full compressor pressure with a large amount of excess air. A fuel pump, governor, and lubricating-oil system completes the list of essential auxiliaries. A safety valve protects against overspeed by passing hot gas directly to the exhaust.

Turbine blades do not differ materially from those of steam practice. For high efficiency of the over-all machine, however, temperatures considerably above those common in steam turbines must be employed. High efficiency is a prime requisite of the compressor since nearly three quarters of the gross turbine output must be used for air compression. Early gas turbines produced little or no useful output principally because of low compressor efficiency. Not until aerodynamic research indicated use of airfoil blade sections in an axial-flow compressor were adiabatic efficiencies of the order of 85 per cent available.

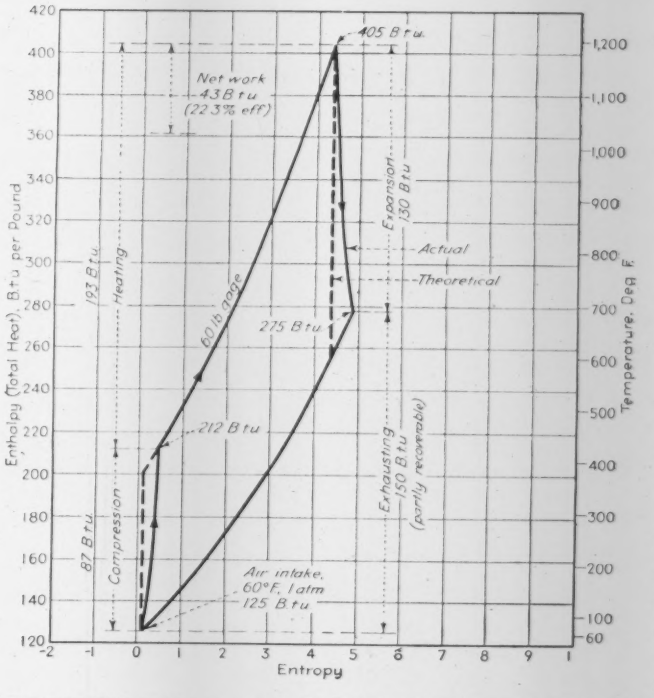
In principle, ordinary air is compressed to any convenient pressure, say 60 psi gage, and passed through a combustion chamber where just enough fuel is fired to bring the "flue" gas temperature up to a predetermined limit satisfactory for the turbine blading, say, 1200 F.

Products of combustion, containing 300 to 600 per cent excess air, expand through turbine blades to atmosphere. Since more work is available from the expanding high-temperature gas than is required for the low-temperature compression, the turbine has an excess of power available for a generator or for mechanical power.

Essentially the same process occurs in a Diesel-engine cylinder. In the engine, air is compressed on the upstroke by absorbing

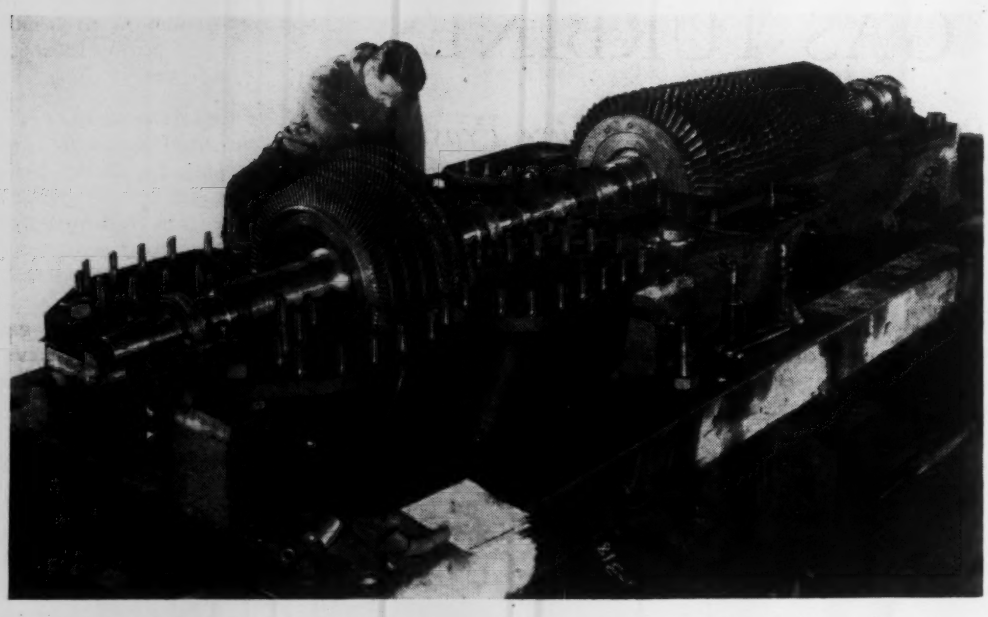


THE CONTINUOUS-COMBUSTION GAS-TURBINE UNIT INCLUDES A HIGH-EFFICIENCY AIR COMPRESSOR, A COMBUSTION CHAMBER, AND A MULTI-STAGE TURBINE


405 B t u.
Net work 43 B t u (22.3% eff)
Expansion 130 B t u
Actual
Theoretical
60 lb. gage
275 B t u.
212 B t u
193 B t u
Heating
87 B t u
Compression
Exhausting 150 B t u (partly recoverable)
Air intake, 60°F, 1 atm 125 B t u
Enthalpy (Total Heat), B t u per Pound
Temperature, Deg F
Entropy

HEAT-ENTROPY DIAGRAM FOR GAS-TURBINE CYCLE RESEMBLES THAT FOR A DIESEL CYLINDER EXCEPT THAT COMPRESSION RATIO IS ONLY FIVE TO ONE

Presented at the National Meeting, Tulsa, Oklahoma, May 8–10, 1944, of the Oil and Gas Power Division, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



ALLIS-CHALMERS 23,000-CFM GAS-TURBINE AXIAL-COMPRESSOR UNIT FOR HOUDRY PROCESS

energy from a flywheel. Oil, forced into the cylinder, is burned (ideally) under constant-pressure conditions. On the down-stroke, hot gas expands and delivers more work than was consumed in compressing the charge. In both engine and turbine, compressor work is two thirds or more of the gross power output of the hot gas. Compression ratios of Diesel engines, however, run up to about 30, whereas the gas turbine is most efficient with ratios below 10.

AMERICAN DEVELOPMENT

Were it not for the fact that the Houdry refining process for aviation gasoline requires large volumes of pressure air for burning off carbon deposits from the catalyst, gas-turbine development in the United States might still be largely confined to supercharging of internal-combustion engines. As it is, however, some 36 gas-turbine sets in sizes from 16,000 to 60,000 cfm are now in operation, eight built by Brown Boveri in Switzerland and the remainder by Allis-Chalmers in Milwaukee. One four-stage "flue-gas" turbine has been described by General Electric.

Operation of these machines, in so far as information is available, has been all that could be expected. The original 1936 machine is still running with its original blades. Many of the sets run for as long periods between inspections as would be expected of steam turbines. It is significant that none of the experience data is discouraging to the next steps proposed for gas-turbine application.

This relatively limited American experience is reinforced by a more extensive background of operation of Velox boilers with gas-turbine axial-compressor sets which supercharge the furnace space. Some 70 of these have been built for land power plants throughout the world. They fire only gas or oil and the temperature of the turbine blades is low, but the many units have established that the gas turbine can carry on in at least one field where it performs a function of which no other apparatus is capable.

Were it not for the outbreak of war, some American application for a power-generating unit would probably by now have become a reality. As the situation stands, test information is available about only one gas-turbine power unit built by Brown Boveri in 1939 for stand-by service. It is located in an underground tunnel at Neuchatel, Switzerland. Simplicity, rather than efficiency, controlled the design of this machine. Its full-load economy approximates 20,000 Btu per kwhr burning fuel oil. The space occupancy of 6.6 cu ft per kw is considerably less than for equivalent steam or Diesel plant, and no water or other means of cooling is required.

Designers are thoroughly aware of the advantages to be gained by burning coal in gas turbines. Brown Boveri experimented with pulverized coal as early as 1941 on a 1500-kw machine, but no information yet available indicates that combustion of solid fuel can be hoped for in the visible future.

IMMEDIATE PROSPECTS

Mentioned among immediate applications for gas-turbine units are (1) locomotive drive, (2) ship propulsion, (3) blast-furnace air supply, and (4) experimental power units. For the first three of these, the gas-turbine power plant can compete with existing prime movers without going to temperatures above 1200 F or relying on apparatus not already tried and proved. The fourth is being encouraged by all concerned to afford opportunity for study of improved cycles, heat-recovery apparatus, and combustion problems under favorable circumstances. Operating experience on intercoolers, regenerators, and other associated apparatus for improving plant efficiency will help bridge the gap between the relatively limited area of certainty and the vague vastness of speculation surrounding the ultimate future of several possible gas cycles.

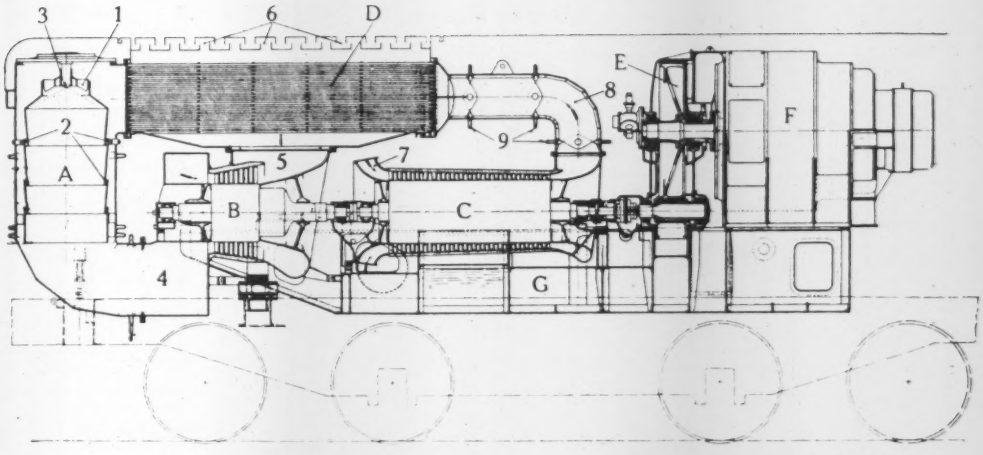
For the immediate future, the question that must be answered is: Who will first be ready to invest money in what may be regarded at best as an experimental unit? The railroads, maritime operators, the steel industry, and power people all have a stake in further development of gas turbines. Of these, the Maritime Commission has taken the initiative by ordering a main propulsion unit of around 2000 hp from the Elliott Company for a Cl-MA-V1 coastwise cargo ship. It is probable that one of the railroads can be persuaded to try an experimental locomotive as soon as war pressure lets up on turbine shops.

From the long-run viewpoint, it would be most desirable for all concerned if the first machine were to be a power unit for installation on the electric lines of some utility company where the best of engineering and operation could be assured unhampered by the extraneous problems inevitably associated with transportation and shipping. However, such a trial would require at least two years and manufacturers are hardly in a mood to sit idly by while some one of their competitors acquires so great a lead.

As soon as the European phase of the war can be seen to take an obvious turn for the better, perhaps by the end of this year, manufacturers will want to build gas-turbine units and the several industries named will want to buy them despite the "growing pains" that normally accompany new application and new apparatus. Indications are that railroad, ship, and power trials will proceed more or less simultaneously.

LOCOMOTIVE DRIVE

Fortunately, the machines required for these immediate uses represent no great step forward into unknown design problems. For example, the locomotive designs proposed by Brown Boveri and Allis-Chalmers include turbine-compressor units not much different from the satisfactory Houdry machines. One 2200-hp



ARRANGEMENT OF GAS-TURBINE LOCOMOTIVE POWER UNIT

(*A*, combustion chamber; *B*, gas turbine; *C*, axial compressor; *D*, air preheater; *E*, reduction gear; *F*, direct-current generator with built-in exciter; *G*, auxiliary frame. The compressed and preheated air is introduced into the combustion chamber as combustion air through the nozzle ring (1), partly as cooling air through slots (2). The fuel enters through the injection nozzle (3). Combustion gas and cooling air mix in chamber (4) and form the driving gas proper, which expands through the gas turbine. The exhaust gases, which still have a high temperature, pass the air preheater from (5) to (6) where they leave through the locomotive roof. The air inlet to the compressor is at (7). The outlet-air duct from the compressor to the heat exchanger is provided with several expansion joints.)

locomotive for the Swiss Federal Railways built by Brown Boveri in 1941 has met all expectations in its test performance, although shortage of oil fuel probably has kept operating miles far below expected use.

Control of this direct-current electric-drive locomotive is simple and nearly automatic. Starting takes eight minutes from cold, requires the services of only one man, involves bringing the gas-turbine unit up to about one-third speed by a small Diesel auxiliary unit (in four minutes), and warming up the main gas turbine while the locomotive can move to its train at 6 mph taking power from the Diesel set. These are reported as actual test accomplishment.

The gas-turbine locomotive drive competes directly with Diesel propulsion since the Diesel has already established a preferred position for road locomotives of large horsepower. Oil fuel and electric drive have been accepted and the railroad operators may be presumed to consider these requirements no serious disadvantage or to be willing to live with the associated problems.

For the first of such units at least, gas-turbine drive will be inferior to Diesel in efficiency; perhaps 25 per cent for the engine and 17 per cent for the turbine would be a fair comparison. To offset this difference, the turbine can burn any oil of reasonable cleanliness and viscosity without reference to cetane number. Such fuel can be purchased for appreciably less money than good Diesel fuel.

The gas turbine offers important advantages that no railroad operator can ignore. For large power, the turbine is compact. The Swiss drive chassis is about 56 ft long and other designs indicate that 5000 hp can be put into a tractor less than 100 ft over-all length, a rather important saving over the three- and four-car articulated units now operating on American runs. Some 7500 hp is possible in a three-car unit, which exceeds any practical assembly of Diesel power yet proposed.

Complete standardization of propulsion units has been suggested in about 2500-hp increments (practically identical with the Houdry machines). Components are reduced to ultimate simplicity, promising maintenance costs below anything yet conceived by railroaders who obtain minimum turnabout time with Diesels by overhauling en route. Usual turbine practice in stationary plants calls for internal inspection at six-month or yearly intervals.

While cost figures have little meaning at this stage of development, and particularly under present conditions, gas turbines are inherently less costly to build than Diesel engines. One quotation of unit price for a complete locomotive with electric drive approximated 70 per cent that of Diesel drive of the same power, but about twice that of standard reciprocating steam engines.

The gas turbine is limited to electric or other indirect drive by the inherent high speed of the rotating machinery. However, torque characteristics are quite satisfactory for geared hydraulic drive since the gas turbine, like any other turbine, has about twice full-load torque at standstill.

An interesting comparison has been furnished by the war-bred mobile steam-power units now being built in 5000-kw, 3000-kw, and 1000-kw sizes. In comparison with the eight-car 3000-kw plants of the General Electric Co. (two boiler cars, one turbine, one switchgear, three cooling-tower, and one maintenance car) the power plant proper of a gas-turbine plant would occupy only a single Pullman chassis plus whatever fuel tenders, switchgear, and maintenance cars might be desired.

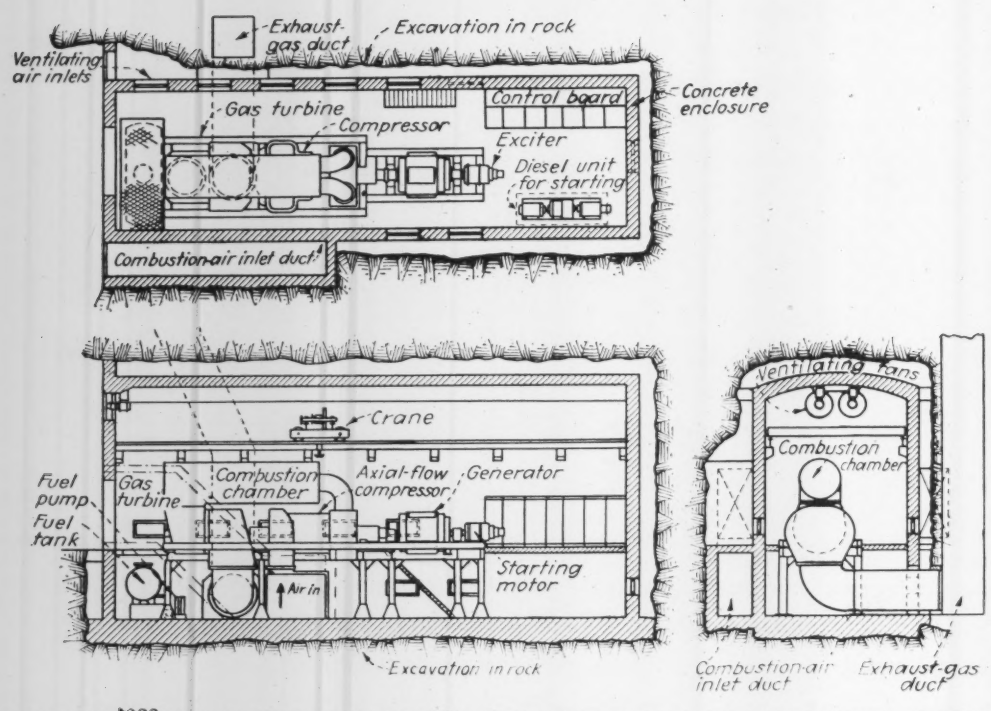
MARINE PROPULSION

Gas turbines have already gone to sea as auxiliaries to Velox boilers. Among the few nonnaval applications that can be discussed is the French passenger ship *Athos II* which was increased from 10,000 shp to 16,000 shp by the addition of a single Velox unit (replacing one of the original seven boilers) and turbines to utilize the added steaming capacity. Details of this and other maritime installations are completely unimportant except to indicate that gas turbines do not suffer from seasickness. Proposed main propulsion units differ in no vital detail from those already familiar to a few marine engineers.

As early as 1940 Brown Boveri undertook construction of a 4000-shp marine propulsion unit for a tanker. Completion of this proposal was interrupted by the outbreak of war, but the significant fact remains that gas-turbine drive was being considered by shipping men long before the present record of experience with Houdry machines was available.

One serious handicap for ship drive is the gas turbine's lack of adaptability for astern operation. Unlike the steam turbine, the astern blading of the gas turbine must turn in a relatively dense atmosphere rather than a perfect vacuum. Brown-Boveri 1940 design included an astern turbine as part of the main propulsion machine, but maritime engineers in this country have decided that the first trial of gas-turbine drive (Elliott) will be direct-current electric, principally because of the reversing requirement.

On the other hand, gas-turbine propulsion units offer a re-



INSTALLATION OF 4000-KW GAS-TURBINE POWER UNIT IN UNDERGROUND TUNNEL AT NEUCHATEL, SWITZERLAND, FOR STAND-BY SERVICE

markably compact engine room for cargo ships, an important advantage operators will hardly overlook. Main elements of the power plant can be grouped well toward the stern of the vessel, least valuable as cargo space. Low weight per horsepower, low space occupancy, and eventually low cost per horsepower are powerful incentives. Economy (better than 0.7 lb fuel oil per shp) equal to steam-turbine drive is expected.

Plans for a cargo-ship drive are well under way. While several manufacturers have proposed designs for marine construction with axial-flow compressors, it is understood that the Elliott Company will furnish the first 2000-hp drive employing the comparatively unknown (in this country) Lysholm twin-rotor screw-type compressor based on Swedish designs.

BLAST BLOWERS

It is significant that the gas turbine, in addition to the obvious power and propulsion applications mentioned, can command immediate consideration for certain process operations never quite satisfactorily accomplished by other prime movers. Specifically, the history of development of the Velox boiler and Houdry process reveal that no other known device could duplicate gas-turbine performance in these fields. Similarly, the gas-turbine set seems better adapted to supply air for blast furnaces than do traditional steam-boiler and turbine-compressor sets.

At least one such gas-turbine compressor set has been supplied to a European steel mill. Blast air is taken from the same axial blower that supplies combustion air for the gas-turbine drive. All the effective power output of the unit is taken as blast air, about 35,000 cfm at 17 psi. A large heat exchanger serves to preheat blast air, a welcome source of low-grade heat not available if other apparatus were used.

For American steel-mill practice, Brown Boveri have designed a 135,000-cfm gas-turbine compressor set for bleeding 60,000 cfm of blast air at 30 psi. The self-contained unit charges its own blast-furnace-gas fuel in a compressor geared up to about 9000 rpm from the main shaft. The unit itself occupies a space only 60 ft long × 13 ft wide, requires no cooling water, and can be installed at only a fraction of the cost of a steam-boiler turbine-compressor plant.

Tests of this type blast compressor have shown thermal efficiency in excess of 18 per cent, substantially higher than equivalent steam plant with boiler and condensing-turbine-driven compressor. For this service, the gas-turbine unit appears to offer less cost, less space, and higher efficiency than any present equipment.

POWER UNITS

Gas turbines for generating power are immediately practical as soon as materials and shop facilities are available to build them. Machines of the Houdry type can be built in sizes from 2000 kw to 10,000 kw with relatively simple heat recovery and intercooling to do better than 14,000 Btu per kwhr at a unit investment cost for equipment alone of around $50 to $70 per kw.

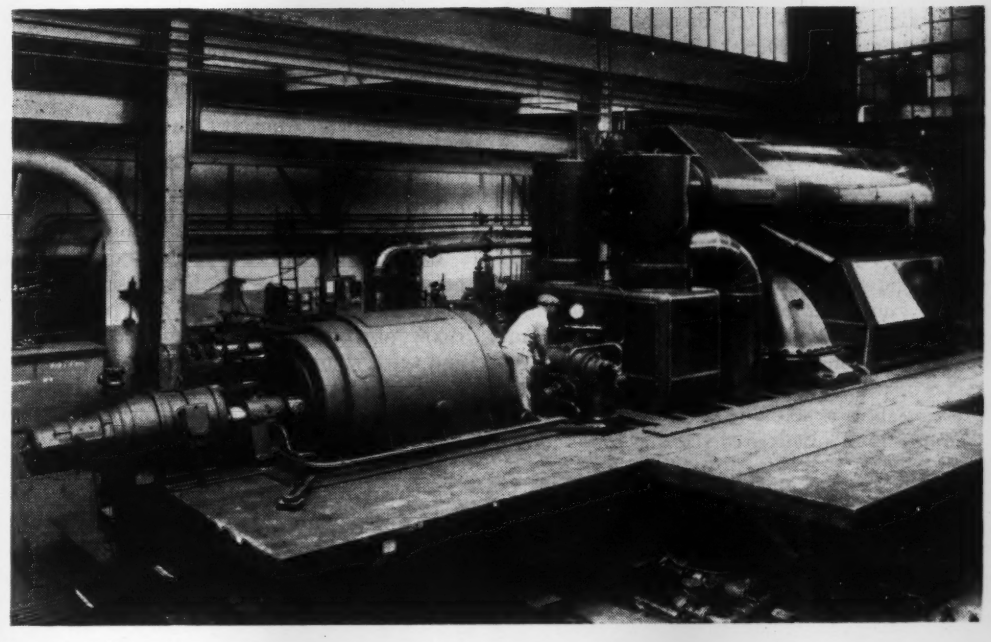
Several manufacturers are known to be working on variations of the gas-turbine cycle for power generation. Oldest in point of experience, of course, is Brown Boveri who would, contingent on getting materials to their shop, immediately contract for a 10,000-kw machine. This would be an improved version of the Neuchatel unit operating at 1100–1200 F with heat recovery, intercooling, and reheat.

Allis-Chalmers, backed by six years of building 28 Houdry units, could conveniently undertake construction of a power unit as soon as labor and materials can be released from restrictions. Such a machine would undoubtedly be built for a temperature around 1200 F and would employ both intercooling and reheat.

Others have given definite indication of preparations to build gas-turbine equipment. Elliott, well versed in construction of Büchi superchargers and many types of compressors, is already under contract for a ship drive. General Electric has proposed both a ship-drive and a locomotive unit. Westinghouse has recently presented a study of a high-pressure closed cycle that could be built in large size for power generation and has undertaken extensive heat-exchanger research. DeLaval and Joshua Hendy, among others, have plans for postwar construction.

FUTURE PROSPECTS

For the several immediate applications already listed, no obvious "if's" are apparent. Designs comparable to those already developed require no great advance in metallurgy or



ONLY POWER UNIT SO FAR CONSTRUCTED IS THIS 4000-KW OIL-FIRED STAND-BY MACHINE SHOWN ON TEST IN BROWN BOVERI SHOP

other extrapolation of existing knowledge. Heat exchangers proposed are neither of excessive size nor greatly different from those with which steam operators are already familiar. Fuel and combustion problems with oil or gas, while not worked out in a variety of detail, appear to offer no serious obstacles to immediate developments.

Commercially, the applications described represent competition with only a small fraction of either Diesel-engine or steam-turbine fields. No definite proposals have been made for construction of gas turbines smaller than 2000 kw or larger than 10,000 kw, an overlap only with the larger sizes of Diesels and smaller sizes of turbines. Compared with smaller steam turbines, the gas turbine is also restricted, for the visible future, with locations normally using gas or oil fuel, a relatively small part of the total.

Imagination is fired, however, by the potential ability of the gas turbine to compete with present prime movers outside the limited fields of immediate application *if one or another hope becomes fact*. If the temperature at which blades can operate can be raised several hundred degrees by advances in metallurgy already in prospect, if some satisfactory method of employing coal fuel is developed, and if large power outputs can be obtained, then the gas turbine can become a most important factor in transportation and power fields. With forced-circulation heating surface surrounding the combustion chamber, it becomes an important means of supplying process steam as well as compressed air.

The three "if's," looking forward from present incomplete knowledge of what wartime advances have been made, seem to present some rather tough problems for research staffs. Raising temperature from accepted steam practice of around 950 F to 1200 F for the gas turbine is a rather large step in itself, much more significant metallurgically than would appear from a simple subtraction of one temperature from another to measure the rise. Every few degrees above 1200 F represents much shorter life for all conventional alloys. Extreme temperatures (up to 2000 F) at which airplane superchargers have been forced to operate for limited periods can be tolerated for military purposes where life of parts is commonly measured in hours. For continuous service in power plants, long life is a prime requisite and much more conservative design must be expected for some years to come.

Adapting combustion chambers to very high rates of firing coal without incurring prohibitive slag and ash troubles with turbine blades seems most difficult in view of the decades spent in perfection of steam-boiler furnaces, not yet completely achieved to the satisfaction of central-station operators. The choice between removing coal ash between the combustion chamber and turbine, or scouring turbine blades with relatively large amounts of abrasive solids, can hardly be contemplated with pleasure by designers.

Most of the electric power made from fuel in this country comes from machines larger than 10,000 kw. Judging from such information as has so far been presented, gas-turbine units larger than this approximate size will be complicated by many shafts and many stages of reheat and intercooling.

Only the first halting steps toward overcoming these limitations can be brought into focus. Brown Boveri and Allis-Chalmers have given serious attention to coal firing, but there is no indication as yet of either success or failure. General Electric and Westinghouse have been leaders in research on the behavior of metals at elevated temperatures, but both exhibit caution in saying how soon and how high in temperature it is safe to go.

Escher Wyss of Switzerland and Westinghouse in this country have proposed closed-cycle designs represented as being capable of large outputs. Escher Wyss suggests transferring heat of combustion through metal to a gas (such as hydrogen) circulating through turbine and compressor blades at high pressure. This arrangement requires removal of heat from the closed cycle at the lower level in the same manner as the steam condenser serves the steam cycle. Since about the same amount of heat must be removed, as in the steam cycle (preferably by employment of cooling water) inordinately large heat exchangers are required as well as the pumps and tunnels associated with condenser practice.

Pumping up the gas-turbine system to an inlet pressure of perhaps 150 psi, as suggested by Westinghouse, requires an auxiliary gas-turbine compressor set of about one fifth the air-flow capacity of the main cycle. The latter operates between atmospheric pressure and cycle pressure to supply air for combustion directly within the main cycle. The complication of equipment required, plus the same cooling problem as exists in steam plants together with lack of provision for coal firing, make it appear that such proposals are in their very early stages.

Another quite different cycle suggested several years ago by

Sulzer Bros. of Switzerland obtains high thermal efficiency of relatively small units by combining Diesel engines with exhaust-gas turbines. One arrangement visualizes the engine driving only a supercharging compressor, all useful power being derived from a generator coupled to the exhaust-gas turbine. While such combinations have received little attention lately because of war conditions, they furnish an almost unlimited variety of power-unit arrangements by changing the division of work between engine and turbine.

One cannot completely overlook the relationship between gas turbines and jet propulsion of aircraft. Briefly, jet propulsion requires either (1) carrying both fuel and oxygen in condensed form aboard the plane, or (2) carrying a compressor on the plane to produce an available pressure differential. The former partakes of the character of a "rocket" and is applicable to producing a large impulse for a short time. The latter offers a means of producing a continuous jet of any desired size and for as long a period as the fuel supply lasts.

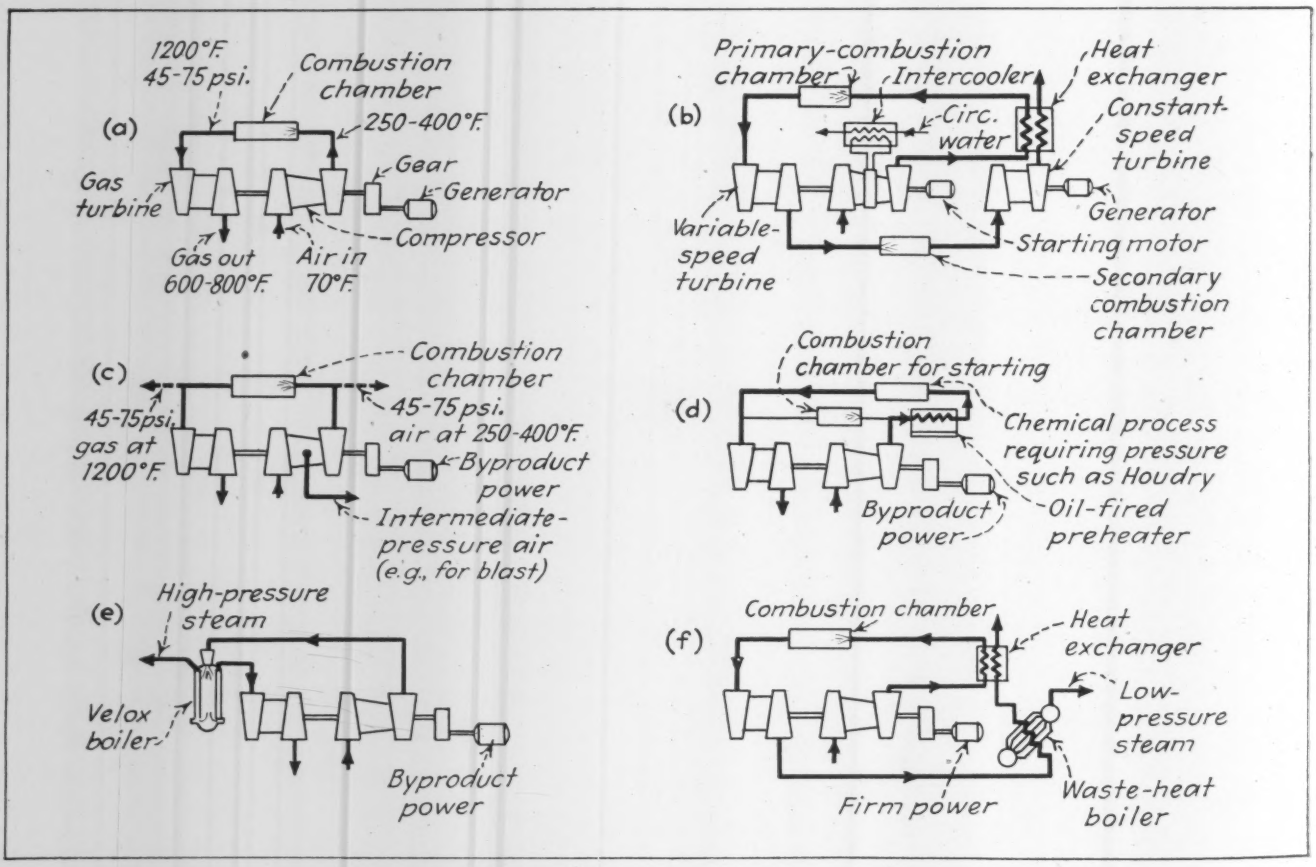
If some form of air compressor is to be carried in flight, the axial-flow type (or some modification) offers least weight and highest efficiency. For this compressor, a gas turbine of very high speed and few stages is definitely superior to any other known drive. Jet propulsion represents a specific case of taking the entire output of a gas-turbine unit as the momentum of a jet of hot gas.

Plane designers choose jet propulsion in preference to the conventional propeller (1) to obtain higher speed, (2) to get greater horsepower per engine than is available from internal-combustion types, (3) to get greater horsepower per engine than can be handled by individual propellers, or (4) to utilize low-grade fuel not suitable for present aircraft engines. Unquestionably, the type of pursuit aircraft now being jet-propelled has developed from the first of these but has also acquired the fourth as a by-product.

For future air transport, the advantage of greater horsepower per engine may be the primary desire with the other features developing as by-products. Present limits of both propeller and gasoline engine seem to be reached at about 2000 hp, approximately the lower limit of gas-turbine size.

Gas turbines of the type that might drive future aircraft can be designed so that practically all the power output can be taken by a shaft and gears to a propeller with the jet as an auxiliary, or so that practically all the power is delivered to the jet, and with some degree of flexibility under control of the pilot as to which supplies the main driving force.

In considering present and future relations between gas turbines and other prime movers, one must be careful to keep his discussion centered on the more or less immediate applications which are real, known, and can be evaluated by commonly accepted economic factors, or else admit that his speculation must depend on the metallurgist, the application engineer, and the inventor for the trend of development of a most versatile type of apparatus. Barring a major miscalculation on the part of practically every manufacturer who has investigated the matter, ship drive, locomotive drive, blast-air units, chemical-process superchargers, and small power units are now practical and economically attractive. Large power units to burn coal, efficiencies higher than those of Diesel engines, and commercial application to aircraft must come from the painstaking work of the research laboratories.



GAS TURBINES OFFER VERSATILE HEAT-BALANCE ARRANGEMENTS

[(*a*) Basic power unit requires no cooling water or auxiliary apparatus; (*b*) 2-stage power unit approaches best steam-plant efficiency with heat exchanger and intercooler; (*c*) unit can supply compressed air at any pressure up to about 75 psi; (*d*) nearly thirty of these process units are helping make aviation gasoline; (*e*) first practical application of the gas-turbine unit was as an auxiliary to the high-pressure Velox boiler; (*f*) by-product steam from waste-heat boilers can be had in limited quantities.]

Progress in GAS-BURNING DIESEL ENGINES *and* PLANTS

By ROBERT CRAMER, JR.

ASSISTANT CHIEF ENGINEER, NORDBERG MANUFACTURING COMPANY, MILWAUKEE, WIS. JUNIOR MEMBER, A.S.M.E.

History of the Development

THE development of the gas-burning Diesel engine has been carried forward in three major stages. The original conception was an engine which would be instantaneously convertible from gas to liquid fuel, to serve areas in which gas was available at favorable rates during only a portion of the time. None of the plants so far built has required this feature because in all those locations natural gas is continuously available.

The first experiments were conducted in March, 1928, at the shops of the author's company, on a three-cylinder, $16^3/_4 \times 22$-in., 240-rpm, two-cycle, 560-bhp, air-injection Diesel engine using manufactured gas of 520 Btu per cu ft high heat value, which was piped to the injection air compressor of the engine at approximately atmospheric pressure. In the first test this gas was was compressed to 1200 psi in a separate small compressor and piped to one cylinder only, where it was injected through the standard air-injection fuel nozzle. No attempt was made to regulate automatically the gas quantity injected, and the oil-injection pump was used to furnish ignition fuel to the gas-burning cylinder. Governing of the fuel supplied was continued to the other two cylinders, which were running on fuel oil in the conventional manner. No difficulty was experienced in getting the gas to burn on the Diesel cycle during these early and relatively crude experiments.

Following this, the gas was piped directly to the injection air compressor of the engine, compressed to 1200 psi, and injected through the standard air-injection nozzles of all three cylinders. The fuel-pump arrangement was not disturbed, except that the governor was disconnected from the regulating shaft, thus permitting the simultaneous injection of any desired proportions of oil and gas. The fuel pumps were timed to deliver oil during each stroke before the needle valve was lifted, as in the conventional air-injection arrangement. No governing system was employed other than hand regulation by means of the starting lever, which brought the needle-valve lifting mechanism into or out of action by shifting the eccentric hubs of the fuel levers.

The foregoing experiments lasted only 4 days but definitely established the following facts:

1 Manufactured gas would ignite and burn satisfactorily on a Diesel cycle without other ignition means, in a conventional combustion chamber.

2 Ignition was somewhat irregular or "bumpy" on gas alone, but could be controlled by the injection of very small amounts of fuel oil, using the gas to inject the oil. The oil used to control the combustion of the gas has been termed "pilot oil."

The second stage in the development of the gas Diesel was the conversion in the field of a five-cylinder, 1250-hp, $20^3/_4 \times 26$-in., 180-rpm, two-cycle, air-injection engine at the Bisbee, Ariz., plant of the Phelps Dodge Corporation, during 1931 and 1932. This work was done under adverse conditions and before the trials could be completed, operations at the plant were abandoned, ending the study. Since the engine was driving a generator, governing means were necessary in this case. Various mechanical governing arrangements were tried; under one scheme the gas was throttled before entering the injection valve, and under another the lift of the needle valve was varied by changing the position of the fulcrum of the lever. In spite of the early abandonment of this experiment, the following additional points were established:

1 Natural gas, having a heat content in the range of 900 to 1100 Btu per cu ft could be burned on the full Diesel cycle as easily as manufactured gas of a lower Btu value, but pilot oil was also required as a combustion stabilizer.

2 Governing by varying the needle-valve lift was feasible; throttling methods were not.

The third stage was the development of the hydraulic valve gear. In June, 1935, the city of Lubbock, Tex., placed an order for a gas-burning Diesel engine, of a design similar to existing Diesel engines, for installation in its municipal power plant. This unit was a 17-in. × 25-in., eight-cylinder, 225-rpm, two-cycle engine rated 1665 bhp at 3200 ft elevation and arranged to be convertible to an air-injection fuel-oil-burning Diesel engine. The time required for conversion was to be a matter of a few hours rather than instantaneous convertibility. The engine was built with a mechanical gear which did not perform satisfactorily in the shop tests. In order to carry out the provisions of the contract under which the engine was purchased, the hydraulic valve gear was then conceived and developed and it proved completely successful from the start. This valve gear of the Lubbock engine has been described by J. J. Graham,[1] superintendent of the Lubbock plant.

No basic changes have been made from the gas-injection system since this first installation. The hydraulic system for lifting the fuel needle valve has proved so successful that it has been applied to air-injection as well as to gas-burning Diesel engines. At present, convertible engines do not include any mechanical levers and pull rods for operating the valves.

Present Hydraulic-Valve System Employed

The present hydraulic-valve mechanism is shown in Fig. 1 and incorporates some mechanical improvements over the original system described by Graham. A standard Bosch fuel pump is driven from the camshaft of the engine. The delivery valve is replaced by an open fitting having an inside diameter slightly less than the plunger diameter and is connected by a tube of the same inside diameter to an actuator cylinder located on the engine cylinder head. A compression spring is located above the fuel-valve lever in place of the tension springs originally used. The actuator plunger lifts the fuel-valve lever through a link with rounded ends.

The present design was evolved to reduce the effective mass of the system, in order to secure better control of the lift of the

Presented at the National Meeting, Tulsa, Okla., May 8–10, 1944, of the Oil and Gas Power Division, of The American Society of Mechanical Engineers.

[1] "Operating Experiences With Gas-Fuel Diesel Engines," by J. J. Graham, paper presented at the National Meeting of the Oil and Gas Power Division, 1938; on file Engineering Societies Library, 29 West 39th Street, New York, N. Y., as miscellaneous papers, 1938, No. 21.

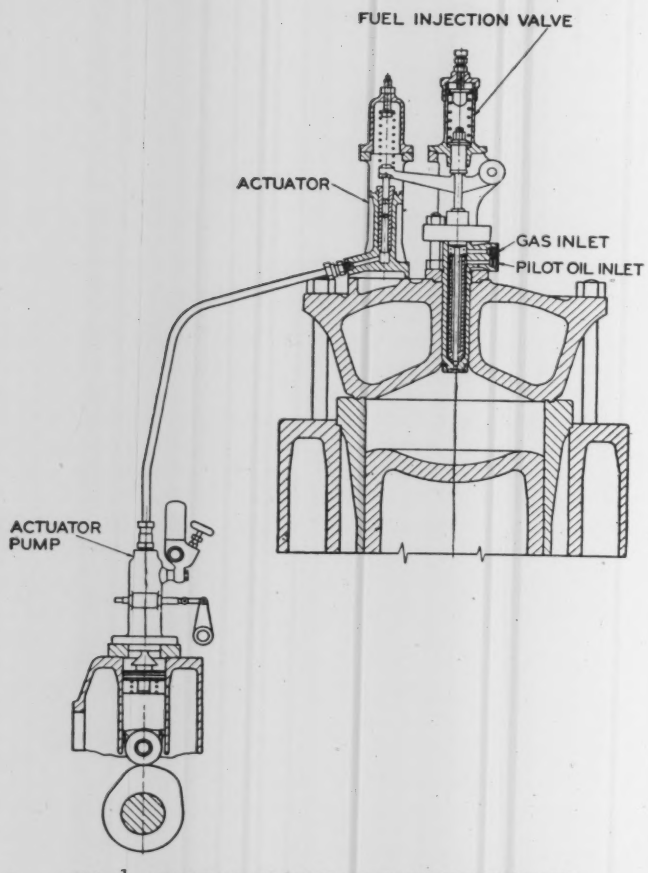


FIG. 1 DIAGRAM OF HYDRAULIC-INJECTION SYSTEM

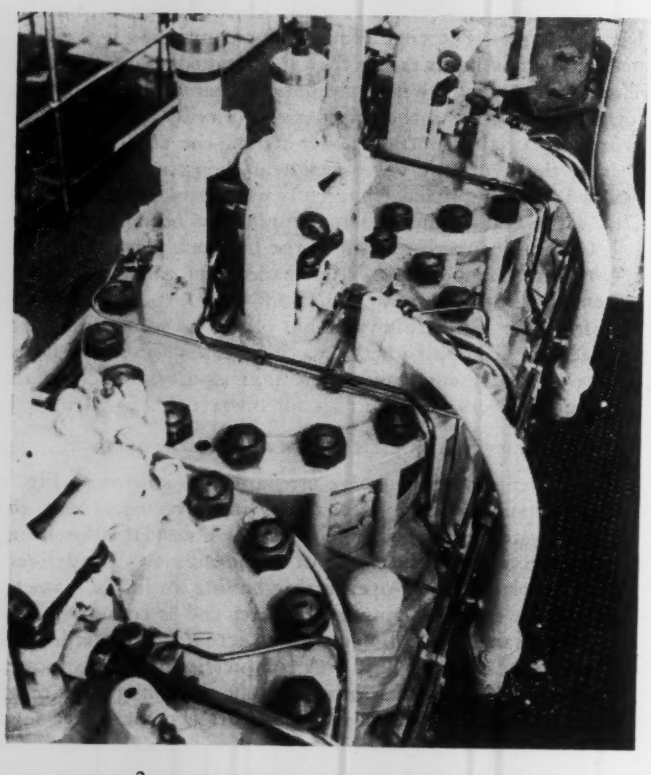


FIG. 2 CYLINDER HEAD OF GAS-DIESEL ENGINE

needle valve. The link construction eliminated the necessity for relatively heavy rollers at the end of the lever. The original system used a tube of relatively small diameter surrounded by a water jacket. Since the inertia of the oil column is proportional to the square of the velocity and directly proportional to the actuator mass, increasing the diameter of the tube until it was equal to the plunger diameter reduced the inertia by reducing the velocity. The benefit of any further increase in diameter was offset by compressibility of the oil and flexibility of the tube. It was then discovered that the lower oil velocity reduced the heating of the oil column to such an extent that a water jacket was no longer necessary, permitting elimination of a troublesome mechanical detail.

The construction of the gas-injection valve is also shown in Fig. 1. It is similar to an air-injection valve, except that it has been simplified by eliminating atomizer plates and other internal parts which are found unessential for the small amount of pilot oil required.

Fig. 2 is a view of a cylinder head showing the needle valve and actuator.

PILOT OIL

The ignition of gas when burned alone in a Diesel engine is erratic. This erratic ignition is manifested by early and rapid firing of the gas on one power stroke, and later or slower firing on another stroke. This phenomenon is accompanied by "bumpy" operation of the engine as a whole, which makes the engine generally unsatisfactory for generator service and causes it to sound irregular and noisy. It is quite possible that the available temperatures at Diesel compression pressures of 480 to 500 psi are proportionately higher in respect to ignition temperature of fuel oil than gas, and that such disturbances as bits of incandescent carbon, variation in compression pressure, because of late burning, and higher initial temperature and pressure of air at the beginning of compression, result in early or late ignition of the gas. The slight cooling of the entering gas as it is throttled from injection pressure to the pressure in the combustion space adds to the uncertainty of the ignition.

Fig. 3 is an indicator card recording two successive cycles of a gas-burning Diesel engine without pilot oil, in which the one cycle has been indicated by a dotted line and the succeeding one by a solid line. Fig. 4 is an indicator card taken on the same cylinder with pilot oil. Great care was exercised to have the indicator in the best possible condition, and the piston practically frictionless. It is to be noted that the compression lines on the first card do not coincide, due perhaps to the early ignition cycle following the late ignition cycle, causing different pressures to exist at the start of the compression strokes.

The amount of heat supplied by the pilot oil is small, approximately 5 per cent of the total required, but so far it has been found indispensable to secure smooth operation.

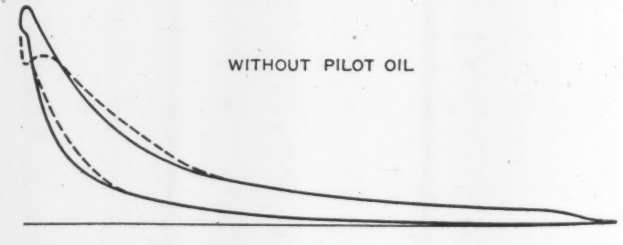


FIG. 3 INDICATOR CARD, WITHOUT PILOT OIL

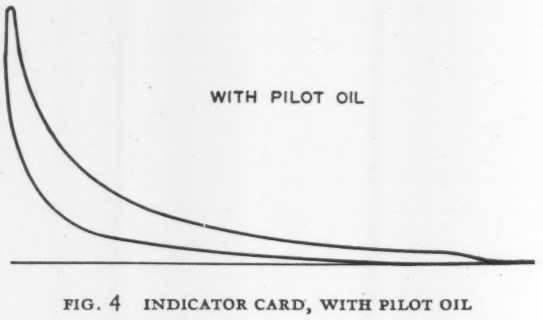


FIG. 4 INDICATOR CARD, WITH PILOT OIL

Pilot oil was originally supplied by multiple fuel-injection pumps of conventional type, as used on small Diesel engines. In the more recent installations, it has been found advantageous to use small individual fuel-injection pumps, which permit convenient adjustment of the pilot oil to the minimum required and also compensation for leakage due to plunger wear of individual pumps. The amount of pilot oil remains constant at all loads but the pumps are connected to the regulating shaft of the engine through a linkage which cuts off their oil supply during stopping and starting periods. This avoids filling the fuel valves with oil, which might cause heavy firing pressures when starting the engine. Fig. 5 shows the pilot-oil pumps on a recent nine-cylinder engine.

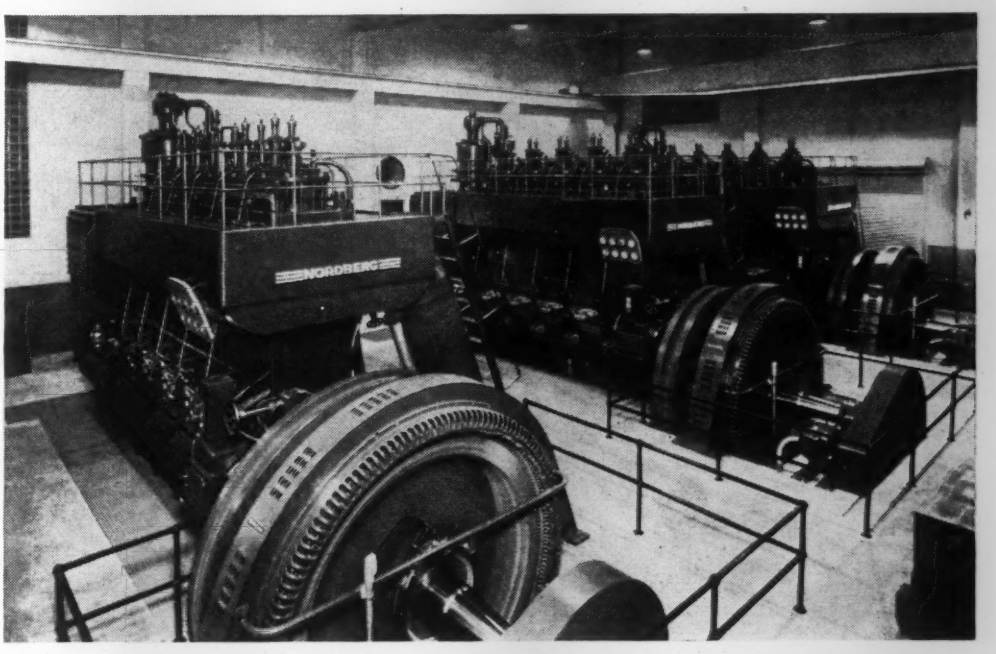


FIG. 6 PLANT OF UNIVERSAL ATLAS CEMENT COMPANY

CONVERTIBILITY

The original idea of instantaneous convertibility has not been abandoned but so far has not been required on any actual installations. All engines have been built so as to be readily convertible from gas operation to either air-injection or solid-injection operation on fuel oil. Furthermore, some engines have been installed as oil-burning engines with provisions for converting later to gas operation. Such provision entails for the most part additional pads on the cylinder heads for supporting the actuator, and extension of the camshaft and cam casing for pilot oil pumps.

The convertible air-injection gas-Diesel engine is built with a three-stage compressor of ample capacity for operation as an air-injection engine. The amount of gas required at maximum load is less than the maximum air requirement. Regulation is accomplished by throttling the suction of the compressor through a regulating valve which maintains constant gas pressure at the injection valves.

Natural gas is available in most localities at a pressure of approximately 60 psi. In such cases, a much smaller compressor is required for engines convertible to solid injection of oil fuel. Regulation is accomplished in the same manner, but is predicated upon the higher suction pressure.

INSTALLATIONS

Gas-Diesel engines aggregating more than 99,000 hp, in unit sizes from 1000 to 3600 bhp, and in plant sizes ranging up to more than 40,000-kw capacity are in daily operation on natural gas. Air-injection engines totaling over 15,000 hp, now running on fuel oil, have been arranged for conversion to gas operation at any time the relative cost of fuel oil and natural gas at those locations makes such conversion desirable.

The development of extensive natural-gas deposits in the mid-continent area of the United States and the existence of a system of gas pipe lines through which gas is distributed over this and distant areas make natural gas available to many localities formerly dependent entirely upon coal and fuel oil. New and important gas pipe lines now under consideration for future construction will make natural gas available to many other communities.

These are very important considerations when viewed in the light of current trends in the production and consumption of petroleum, to

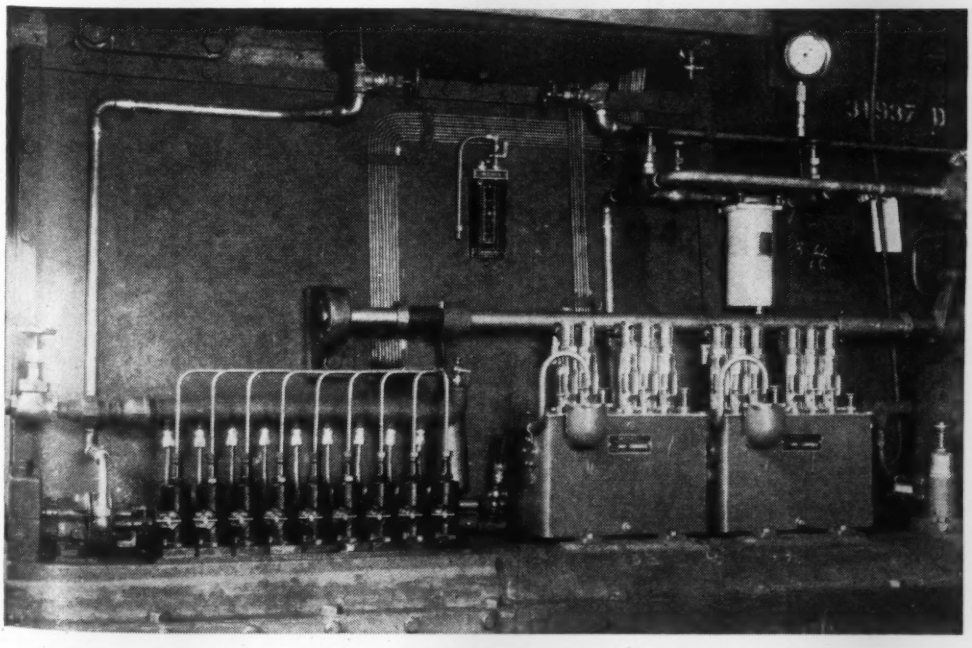


FIG. 5 PILOT OIL PUMPS, NINE-CYLINDER ENGINE

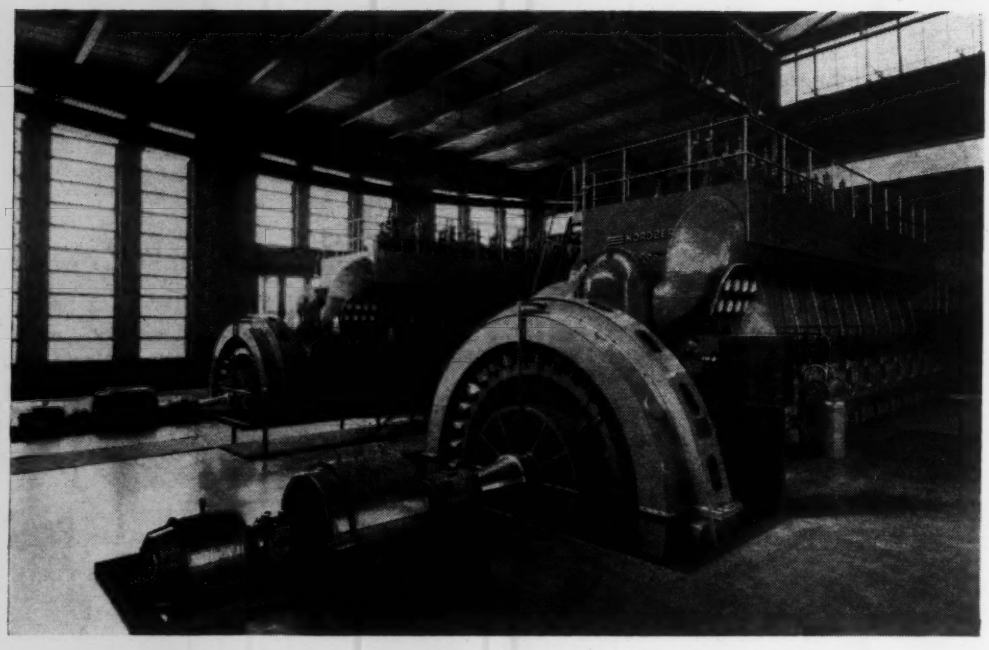


FIG. 7 PLANT OF IOWA ELECTRIC LIGHT AND POWER COMPANY

the use of which conventional Diesel engines are confined.

Test results on the first gas-Diesel engine installed in the Municipal Electric Plant at Lubbock, Tex., have been presented by J. J. Graham in the paper[1] previously cited. By applying the correction factor given for the heat value of the gas, the fuel consumption reported was as follows:

Load	4/4	3/4	1/2
Gas, Btu	11,260	10,228	10,885
Pilot oil, Btu	650	900	1,400
Total Btu per kwhr	11,910	11,128	12,285

All values given are high heat values. Performance data of this engine are also presented for a period of 20 months ending May 31, 1938, during which time the engine generated 11,105,100 kwhr on 127,355,000 cu ft of natural gas, at a cost of $16,730.96; and 75,000 gal of pilot oil at a cost of $3000; a total fuel cost of 1.77 mills per kwhr. The average fuel consumption during this period was 11,427 Btu per kwhr, based on high heat value and including pilot oil.

Typical of the performance records of other gas-Diesel engines is that of a 2430-hp unit installed by the Indian Irrigation Service, Department of Interior, at Coolidge, Ariz., and described by R. G. Hornberger.[2] The operating data reported in this paper for the period from August 1, 1939, to July 31, 1940, is summarized in Table 1.

All heat values for gas and pilot oil referred to in this paper are gross or high heat values. The low or effective heat values, on which gas consumption of conventional spark-ignition gas engines is usually based, are about 10 per cent lower, and, hence, corresponding fuel-consumption figures would be about 10 per cent lower.

Fig. 6 shows the Atco, Tex., plant of the Universal Atlas Cement Corporation. There are three five-cylinder, 2000-hp, 21 × 29-in. engines, all convertible to air-injection oil engines but presently running on natural gas. The pumps, actuators, and connecting tubing can be clearly seen.

Fig. 7 shows an installation of two nine-cylinder, 3600-hp engines operating as air-injection oil engines at present, but arranged for conversion to gas operation.

Fig. 8 shows one of the bays of the Diesel plant of the Aluminum Company of America, each bay having nine 3600-bhp gas-Diesel engines, operating on gas and convertible to oil-burning, with solid injection. The capacity of this plant totals 64,800 bhp and it is the world's largest Diesel plant today. This capacity is in addition to the fifty spark-ignition gas engines, forming part of the same plant, the combined capacity of the entire plant being 123,050 hp.

TABLE 1 PERFORMANCE DATA OF 2430-HP GAS-DIESEL ENGINE

Total power generated, kwhr	12,588,300
Gas consumed, cu ft	125,311,000
Gas consumed, Btu	132,680,000,000
Pilot oil consumed, gal	57,184
Pilot oil consumed, Btu	8,041,000,000
Total Btu consumed	140,721,000,000
Average fuel consumption, Btu per kwhr	11,579
Average fuel cost	2.35 mills per kwhr

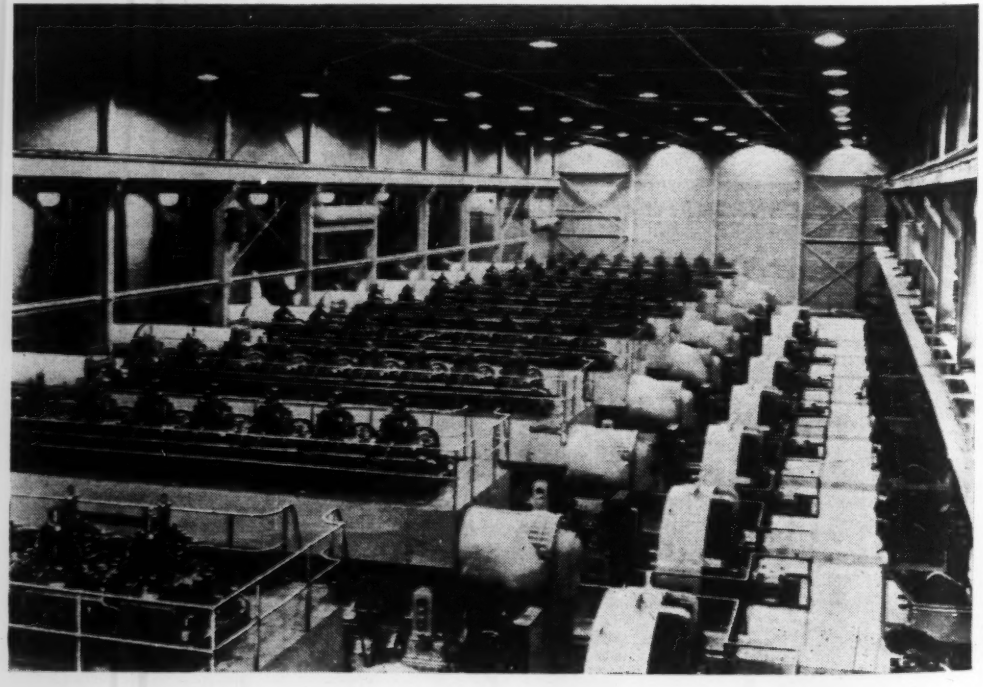


FIG. 8 PLANT OF ALUMINUM COMPANY OF AMERICA

[2] "Year's Service Record Shows Gas Diesel Economy," by R. G. Hornberger, *Power*, vol. 84, 1940, pp. 724–727.

The Basic GAS-TURBINE PLANT *and Some of Its Variants*

By J. KENNETH SALISBURY

TURBINE ENGINEER, GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y

THE volume of recently published data concerning the constant-pressure combustion-gas turbine has made most engineers reasonably familiar with its operating principle. It may be well, however, to discuss briefly the method by which power is produced. Fig. 1 illustrates diagrammatically the modern constant-pressure combustion-gas turbine which consists in its simplest form of a compressor, a combustion chamber, and a turbine.

The term "constant pressure" is used to distinguish the machine under discussion from the explosion gas turbine such as, for example, the Holzwarth type. It does not indicate that the pressure is constant for operation at all loads, but rather that a steady-flow process is used. The ratio of the maximum pressure in the cycle (at the compressor discharge or the turbine inlet) to the compressor-inlet pressure is designated as the "pressure ratio."

In the constant-pressure unit, atmospheric air is compressed in the compressor to several atmospheres pressure and then taken to a combustion chamber into which fuel is injected. The burning of fuel raises the temperature of the compressed air, which is then taken to the turbine in which it produces power, just as superheated steam produces power in a steam turbine. The greater part of the power produced (about two thirds) is required to drive the compressor. Only the remainder is available for doing useful work.

The history of the past two centuries is replete with records of the attempts of many people to find a satisfactory prime mover operating on combustion gases. It has been and still is probably the most frequently "invented" of all prime movers. The inventors range from English preachers to scientists of the highest type. Fig. 2 indicates some of the important dates in the history of the development of the gas turbine and the combustion engine. Note that the more important of the early efforts began at approximately the same date.

Many of the original inventions in the development of the combustion machine consisted of explosion engines, such as Huyghen's gunpowder engine of 1680, and Robert Street's turpentine explosion engine of 1794, which exploded vaporized turpentine by means of a firing aperture in the cylinder wall. Beau de Rochas made an important contribution when, in 1856, he proposed the present Otto cycle, the cycle used in the modern automotive engine. The consummation of his proposal had to await the ingenuity of Otto and Langen, who built a free-piston engine in 1867, operated on Beau de Rochas' cycle. Meanwhile in 1860 Lenoir built the first commercially successful internal-combustion engine. It is recorded that this engine was used in carriages and in a ship, and even that a short flight was made in a balloon powered by a Lenoir engine. Lenoir's engine occupied the center of the stage until the Otto "silent" engine was built in 1876. In about 1864, John Ericsson, a Swede, who constructed the Civil War *Monitor*, built engines to power a U. S. naval vessel of 2200 tons. He used four engines, each having a bore of 14 ft and a stroke of 6 ft, which operated at 9 rpm and developed the tremendous power of 300 hp. Obviously these engines were not very promising. In 1895 Dr. Rudolph Diesel gave the world his Diesel engine which today is a strong competitor in the prime-mover field.

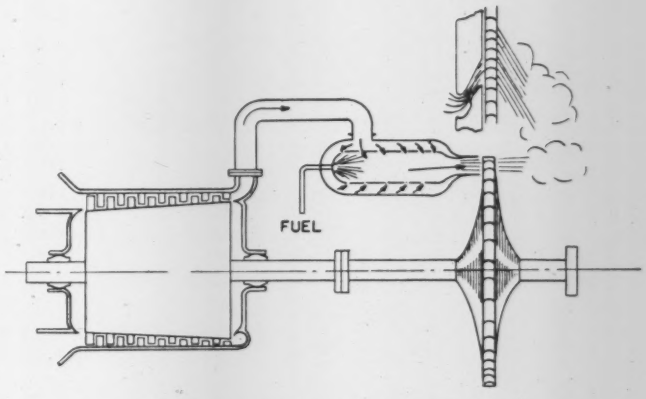


FIG. 1 MODERN GAS-TURBINE POWER PLANT

SOME DATES IN EARLY HISTORY

THE GAS TURBINE		THE COMBUSTION ENGINE	
1680	BISHOP WILKINS' GAS TURBINE FOR "TURNING A SPIT, ROCKING A CRADLE, OR CHIMING BELLS"	1680	HUYGHEN'S GUNPOWDER ENGINE
1791	JOHN BARBER'S DESIGN USING DISTILLED COAL, OIL OR WOOD	1794	STREET'S TURPENTINE EXPLOSION ENGINE
1850	FERNIHOUGH - A PRODUCER GAS TURBINE	1816	STIRLING'S REGENERATIVE HEAT ENGINE
1884	PARSON'S ORIGINAL PATENT INCLUDED GAS TURBINE	1856	BEAU DE ROCHAS PROPOSED A CYCLE
1895	C.G. CURTIS OBTAINED U.S. PATENTS	1860	LENOIR'S ENGINE WAS THE FIRST COMMERCIALLY SUCCESSFUL ONE. NO COMPRESSION OF CHARGE WAS USED
1902	DR. S.A. MOSS OPERATED A GAS TURBINE WHEEL	1864	JOHN ERICSSON INSTALLED 4 ENGINES IN A U.S. NAVAL VESSEL
1904	GENERAL ELECTRIC OPERATED GAS TURBINES AT LYNN, MASS. AND SCHENECTADY	1867	OTTO AND LANGEN'S FREE PISTON ENGINE USED BEAU DE ROCHAS' CYCLE
1907	ARMENGAUD AND LEMALE REPORTED 3 YEARS SUCCESSFUL OPERATION IN PARIS OF A GAS TURBINE USING A RATEAU CENTRIFUGAL "POLY CELLULAR" COMPRESSOR 100 LBS. PRESSURE, 65% EFFICIENCY	1876	OTTO SILENT ENGINE
		1895	DIESEL'S ENGINE

MODERN USE
- BUCHI SUPERCHARGED ENGINES
- VELOX TYPE BOILERS
- INDUSTRIAL PROCESSES
- AIRCRAFT SUPERCHARGERS
- LOCOMOTIVES

FIG. 2 DATES IN EARLY HISTORY

Tracing gas-turbine progress it is recorded that in 1680, Bishop Wilkins in a book called "Mathematical Magick" presented an idea for what is probably the first gas turbine. His ambitions were modest enough. His claims for his gas turbine were that it was suitable for "turning of a spit, reeling of yarn, the chiming of bells, the rocking of a cradle, and diverse other demestick functions." In 1791, John Barber proposed the first important gas-turbine design. His plant was intended to operate on distilled coal, wood, or oil and, significantly, embodied a compressor driven by the turbine through chains and gears. In 1850, Fernihough obtained a patent on a producer-gas turbine. In 1884, Parsons described in his original patent an idea remarkably close to our present conception of the combustion-gas turbine. Quoting from his patent he said that, "Such a fluid pressure producer (compressor) can be combined with a multiple motor (turbine) according to my invention to obtain motive power from fuel or combustible gas of any kind. For this purpose I employ the pressure pro-

Presented at the National Meeting, Tulsa, Okla., May 8–10, 1944, of the Oil and Gas Power Division, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

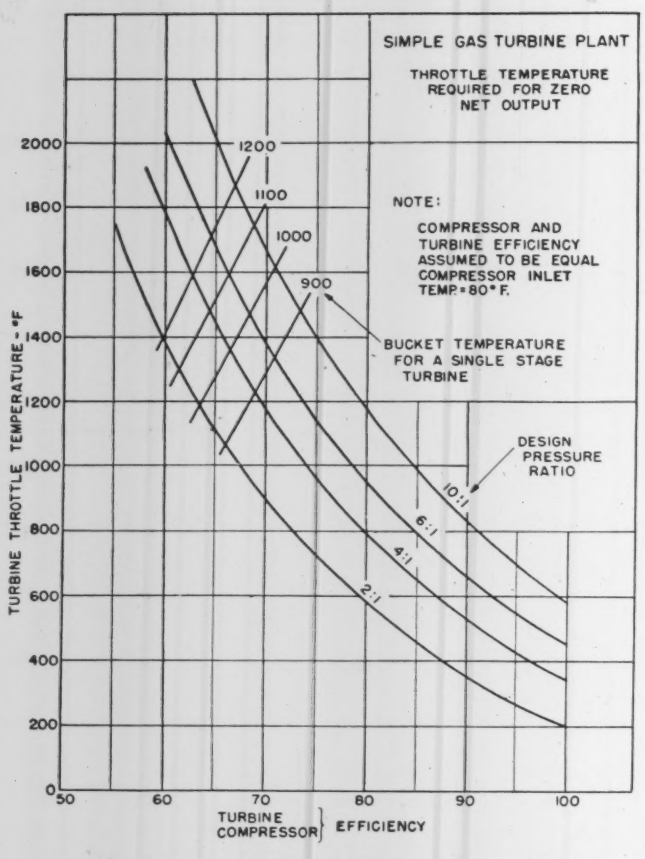


FIG. 3 MINIMUM TEMPERATURES FOR USEFUL OUTPUT

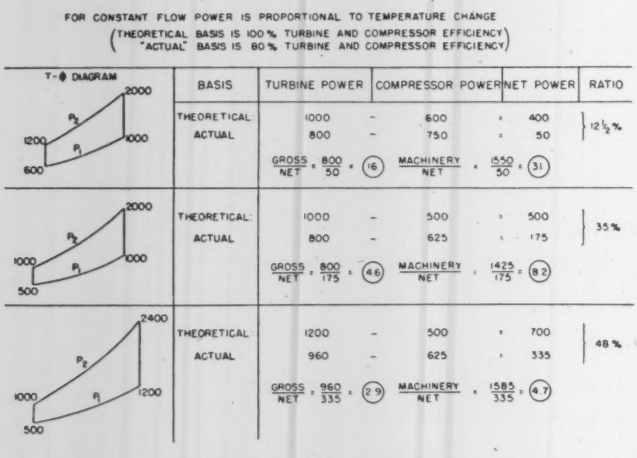

FOR CONSTANT FLOW POWER IS PROPORTIONAL TO TEMPERATURE CHANGE
(THEORETICAL BASIS IS 100% TURBINE AND COMPRESSOR EFFICIENCY
"ACTUAL" BASIS IS 80% TURBINE AND COMPRESSOR EFFICIENCY)
T-Φ DIAGRAM
BASIS
TURBINE POWER
COMPRESSOR POWER
NET POWER
RATIO
THEORETICAL 1000 - 600 = 400
ACTUAL 800 - 750 = 50
12½%
GROSS/NET = 800/50 = 16
MACHINERY/NET = 1550/50 = 31
THEORETICAL 1000 - 500 = 500
ACTUAL 800 - 625 = 175
35%
GROSS/NET = 800/175 = 4.6
MACHINERY/NET = 1425/175 = 8.2
THEORETICAL 1200 - 500 = 700
ACTUAL 960 - 625 = 335
48%
GROSS/NET = 960/335 = 2.9
MACHINERY/NET = 1585/335 = 4.7

FIG. 4 EFFECT OF TEMPERATURES ON OUTPUT

ducer to force air . . . into a furnace in which . . . may be introduced fuel . . . From the furnace the products of combustion can be led . . . to the multiple motor which they actuate. The pressure producer and multiple motor can be mounted on the same shaft, the former to be driven by the latter. . . . In some cases I employ water or other fluid to cool the blades . . . to effect their protection."

In 1895, Charles G. Curtis obtained a U. S. patent on a gas turbine. In 1902 Dr. Sanford A. Moss operated a gas-turbine wheel at Cornell University. In 1904, the General Electric Company operated gas turbines at both Lynn, Mass., and Schenectady. Thus this company has been interested in the gas turbine for 40 years. Dr. Moss was instrumental in the development of the centrifugal compressor and has continuously been interested in the gas-turbine-powered supercharger which is playing such an important part in the current war.

In 1907 Armengaud & Lemale reported 3 years' successful

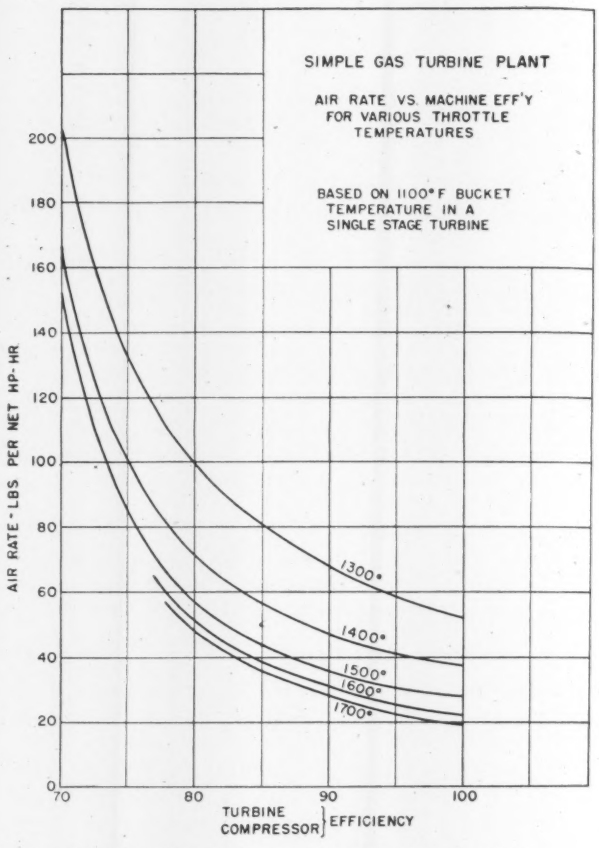


FIG. 5 AIR RATE VERSUS MACHINE EFFICIENCY

operation in Paris of a gas turbine. This unit used a Rateau "polycellular compressor" of the centrifugal type, having about 65 per cent efficiency and connected to a rebuilt steam turbine operating on combustion gases.

All of the early inventors encountered extreme difficulty in obtaining useful output from their machines. The reasons for this difficulty are today quite obvious. For example, Fig. 3 illustrates the minimum turbine-inlet temperature at which useful output can be obtained, plotted against machine efficiency. Note that with Armengaud's 65 per cent efficient compressor it would be necessary at only 2 atm compression pressure to use an initial turbine temperature of about 1100 F, in order to generate sufficient power barely to drive the compressor. For this condition he would have obtained exactly zero output, provided his turbine efficiency was also 65 per cent, and provided pressure drops in the system were small. Modern turbine and compressor efficiencies are in the 80 to 85 per cent range, hence useful output can be obtained with temperatures as low as about 600 F.

Fortunately the output of the gas-turbine power plant increases very rapidly as the turbine initial temperature is increased, or as the compressor-inlet temperature is decreased. This fact is illustrated in Fig. 4 in which are shown progressively the effects of

1 Decreasing the compressor-inlet temperature, and
2 Increasing the turbine-inlet temperature.

Fig. 4 assumes, for convenience, that the flow and specific heat of the fluid have particular values such that the temperature change represents numerically the output in horsepower (the flow would be 10,600 lb per hr when using air). The temperatures chosen are arbitrary. The pressure ratio used is such that the adiabatic temperature ratio is exactly 2:1, a pressure ratio of about 11:1, when using air as a fluid. The outputs are shown on both a theoretical and an "actual" basis, the theoretical and actual bases being 100 and 80 per cent ma-

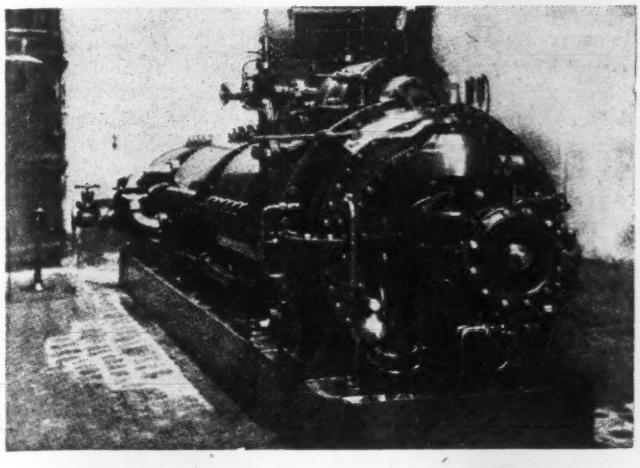


FIG. 6 ARMENGAUD'S 300-HP GAS TURBINE

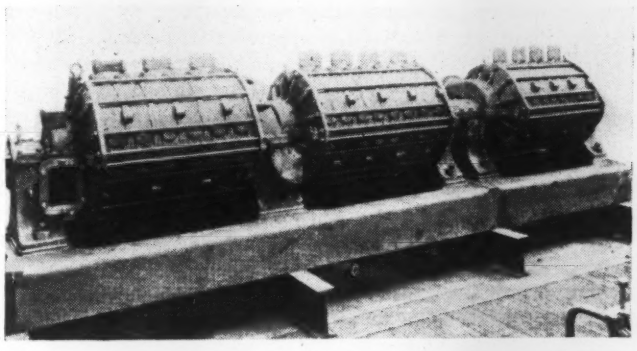


FIG. 7 RATEAU 3-CYLINDER COMPRESSOR

chine efficiency, respectively. The circled figures indicate clearly the rapid decrease in the ratio of the gross to the net turbine power, as well as in the machinery power to net power ratio. Note also that the ratio of actual to theoretical net power increases very rapidly as the turbine temperature is increased and compressor-inlet temperature is decreased.

The early inventors were forced to use machines of tremendous size because of limitations in machine efficiency and temperature. This fact is illustrated in Fig. 5 in which is shown the air rate (analogous to steam rate) of a gas turbine, plotted against machine efficiency for various turbine inlet temperatures. These curves assume operation at the pressure ratio required to give a constant turbine-bucket temperature of 1100 F in a single-stage turbine, such as the author's company contemplates in its present developmental work. Whereas the early experimenters were forced to use cycles having air rates higher than 200 lb per hp-hr, together with machinery which was consequently very bulky, the modern gas turbine, with its high-efficiency machinery and high initial temperatures, is able to operate at air rates of less than one quarter of this value. Thus progress in aerodynamic design and metallurgy, resulting in better efficiencies and higher throttle temperatures, has definitely brought the physical size of the gas turbine into the range of practicability.[1]

When designed for modern conditions of temperature and efficiency the gas-turbine power plant is extremely compact, light in weight, and approaches in efficiency some of the other modern prime movers. This compactness and simplicity is in fact one of its outstanding virtues. By contrast with the modern gas-turbine plant, Armengaud's gas turbine, shown in Fig. 6, was physically very long but developed only 300 hp.

[1] The physical size of rotating machinery is largely determined by the volume flow which it must handle, especially when freedom is permitted in the choice of a rotational speed.

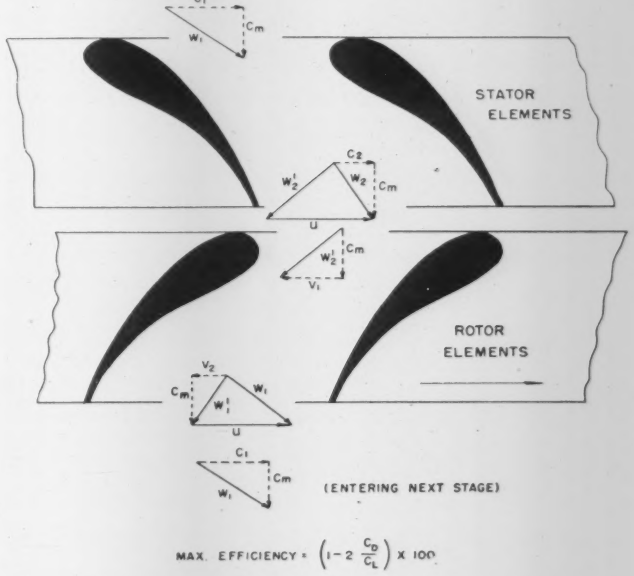
The compressor for this gas turbine shown in Fig. 7, a three-cylinder centrifugal machine designed by Rateau, developed about 100 psi pressure at the discharge with an efficiency of about 65 per cent.

THE AXIAL-FLOW COMPRESSOR

The Rateau polycellular compressor clearly indicates that there was a real need for an efficient, compact, high-capacity compressor. One answer to this need is the axial-flow compressor; essentially a "turbine" driven by external means, which increases the pressure of the fluid supplied to it rather than decreases it, as in the case of an ordinary steam turbine. It is interesting to note that the axial-flow compressor employs blade designs which are taken from the aeronautical-engineering field. All of the information developed by aerodynamicists is available to the designer of axial-flow compressors. The Brown-Boveri Company pioneered in the development of this modern kinetic-type compressor and has made many useful contributions to the design of such machines.

The axial-flow compressor is a comparatively new type of machine, hence many engineers are not entirely familiar with its method of operation. Velocity diagrams may be drawn for the axial-flow-compressor stage in much the same manner as they are drawn for a steam-turbine stage. The conventional airfoil section, when arranged in a grid similar to turbine nozzles, possesses the property of deflecting through a small angle the fluid which passes through it. This property is utilized in increasing the pressure of the fluid. The applicable velocity diagrams are shown in Fig. 8 for a typical intermediate stage of the compressor.

Entering the stator passages with a velocity W_1, the compressor blade causes a turning of the stream so that at the exit of the stator the velocity has the numerically smaller value W_2. The axial component is constant since the inlet and exit areas are approximately equal, but the whirl component is reduced from C_1 to C_2 by the action of the blade. The kinetic energy of the leaving stream is less than that of the entering stream, the reduction having been transformed by diffusion into potential or pressure energy. The "whirl" or tangential component of the velocity entering the rotor is C_2 which, relative to the rotor, becomes V_1. The relative velocity entering the rotor is W'_2. The whirl velocity is again reduced in passing through the airfoil grid to V_2, giving a net total relative velocity W_1. The absolute velocity entering the following stator element is obtained by adding vectorially the wheel speed U, giving a value of W_1 identical with the original entering ve-



MAX. EFFICIENCY = $\left(1 - 2\,\frac{C_D}{C_L}\right) \times 100$

FIG. 8 AXIAL-FLOW-COMPRESSOR VELOCITY DIAGRAMS

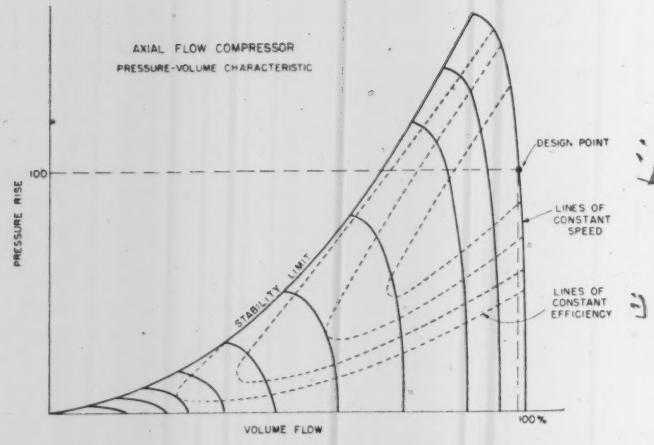


FIG. 9 TYPICAL CHARACTERISTICS OF THE AXIAL-FLOW COMPRESSOR

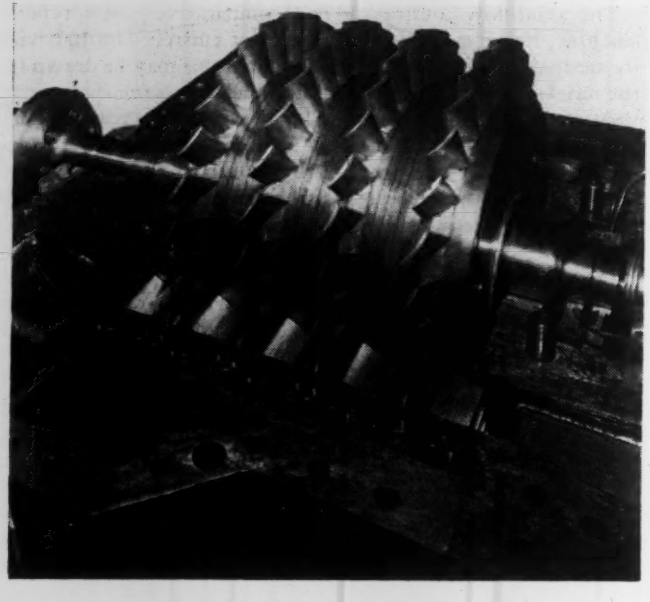


FIG. 10 AN EXPERIMENTAL COMPRESSOR

locity. Diffusion has again taken place, in the rotor, resulting in a further increase in pressure. In essence the stator reduces the whirl component of the entering velocity and the rotor again restores this whirl component, thus consuming power and causing an increase in pressure.

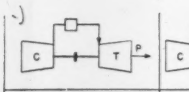
The axial-flow compressor has over-all external characteristics of the type shown in Fig. 9. It will be noted that it is essentially a constant-volume-flow device at any given speed. Increase in the discharge pressure causes only a slight reduction in the volume flow passed by the compressor. Eventually, however, increase in the discharge pressure causes an excessively high "lift" of the airfoil sections and results in a sudden breaking down of their diffusing properties. At this time the compressor is likely to become unstable and destructive vibratory stresses may be set up. The dash lines are lines of constant efficiency, indicating that, as the flow and pressure are decreased, the efficiency also decreases. Shown in Fig. 10 is a 4-stage developmental axial-flow compressor. Note the angle setting of the compressor blades. They are at approximately 45 deg to the longitudinal axis of the compressor, the optimum setting for best stage efficiency.

THE TURBINE

There are several possible arrangements of the turbine in a combustion-gas-turbine power plant, all of which are theoretically identical in thermal efficiency. Furthermore it is possible to use either a single or a multistage turbine of any type. The primary objective is both high plant efficiency and compactness. The author's company has chosen a single-stage turbine of the impulse type which, although admittedly somewhat lower in efficiency than a multistage turbine, has the compensating advantage of permitting higher initial turbine temperatures. The expansion through the turbine occurs in a single step and results in a rapid reduction of temperature before the hot gases come in contact with the buckets. The only parts which are subjected to the maximum temperature of 1600 F are those which are stationary and which have relatively low stresses. The most highly stressed part of the machine, namely, the wheel and buckets, is subjected to a reduced temperature when a single stage is used.

Shown in Fig. 11 are three of the possible arrangements of turbine, all identical in thermal performance. The first indicates the arrangement least susceptible to the variables of temperature and machine efficiency. Reduction of temperature or machine efficiency results simply in reduction of the net output without prejudice to successful operation of the power plant. All of the excess power is available for acceleration of the plant when no load is applied at the output coupling. Starting problems are minimized and great simplicity results.

The parallel arrangement of turbine, in which a separate power turbine is employed, has as its chief advantage the complete freedom permitted in location and speed of the power tur-



	COMP TURBINE / POWER TURBINE	COMP TURBINE / POWER TURBINE	COMP TURBINE / POWER TURBINE
THERMAL EFF'Y	18.6 %	18.6 %	18.6 %
OVERALL PR. RATIO	6:1	6:1	6:1
THROTTLE TEMP	1600°F	1600°F	1600°F
NET POWER OUTPUT	100	100	100
PRESSURE RATIO	6:1	6:1 / 6:1	3.18:1 / 1.89:1
TURBINE POWER	316	216 / 100	216 / 100
THROTTLE TEMP	1600°F	1600°F / 1600°F	1600°F / 1149°F
EXHAUST TEMP	940°F	940°F / 940°F	1149°F / 940°F
THROTTLE FLOW	100%	68.3% / 31.7%	100% / 100%
BUCKET TEMP	1100°F	1100°F / 1100°F	1275°F / 1000°F
COMMENTS	1. GOOD ACCELERATION 2. GOOD STARTING CHARACTERISTICS 3. INDEPENDENT SPEED-TEMPERATURE RELATION	1. POWER TURBINE SPEED INDEPENDENT OF COMPRESSOR SPEED 2. FREEDOM IN LOCATION OF POWER TURBINE 3. OPERATING TEMPERATURE FIXED BY EFFICIENCY OF UNITS	1. POWER TURBINE SPEED INDEPENDENT OF COMPRESSOR SPEED 2. FREEDOM IN LOCATION OF POWER TURBINE 3. OPERATING TEMPERATURE FIXED BY EFFICIENCY OF UNITS 4. EXCESSIVE BUCKET TEMPERATURE

FIG. 11 ALTERNATIVE TURBINE ARRANGEMENTS

bine. In order that the compressor may use all of the power produced by the compressor turbine, a particular temperature is required at the compressor-turbine inlet for a given design pressure ratio. Subsequent decrease in machine efficiency would require increase in the turbine-inlet temperature to obtain balance. In addition, a conduit suitable for high temperatures is required to transport the hot gases to the power turbine unless, of course, a separate combustion chamber is utilized at the inlet to the power turbine, an entirely reasonable arrangement. Zero power output can be obtained by bypassing the power turbine through an equivalent restriction, whereas in the single-turbine arrangement, a reduction in temperature will accomplish the same result.

The series arrangement of the turbine requires a particular division of the pressure drop between the inlet and the final exhaust. The pressure drop is divided by means of proper design of the respective nozzle areas. Here again any change in the efficiency of the compressor turbine must be compensated for by change in the turbine temperature. The acceleration problem may be somewhat alleviated in certain instances by by-passing the exhaust gases to the atmosphere, thus momentarily increasing the power of the compressor turbine. Note that the bucket temperature for this arrangement becomes rather high even though a single-stage turbine is used.

A good conception of the single-shaft gas-turbine power-

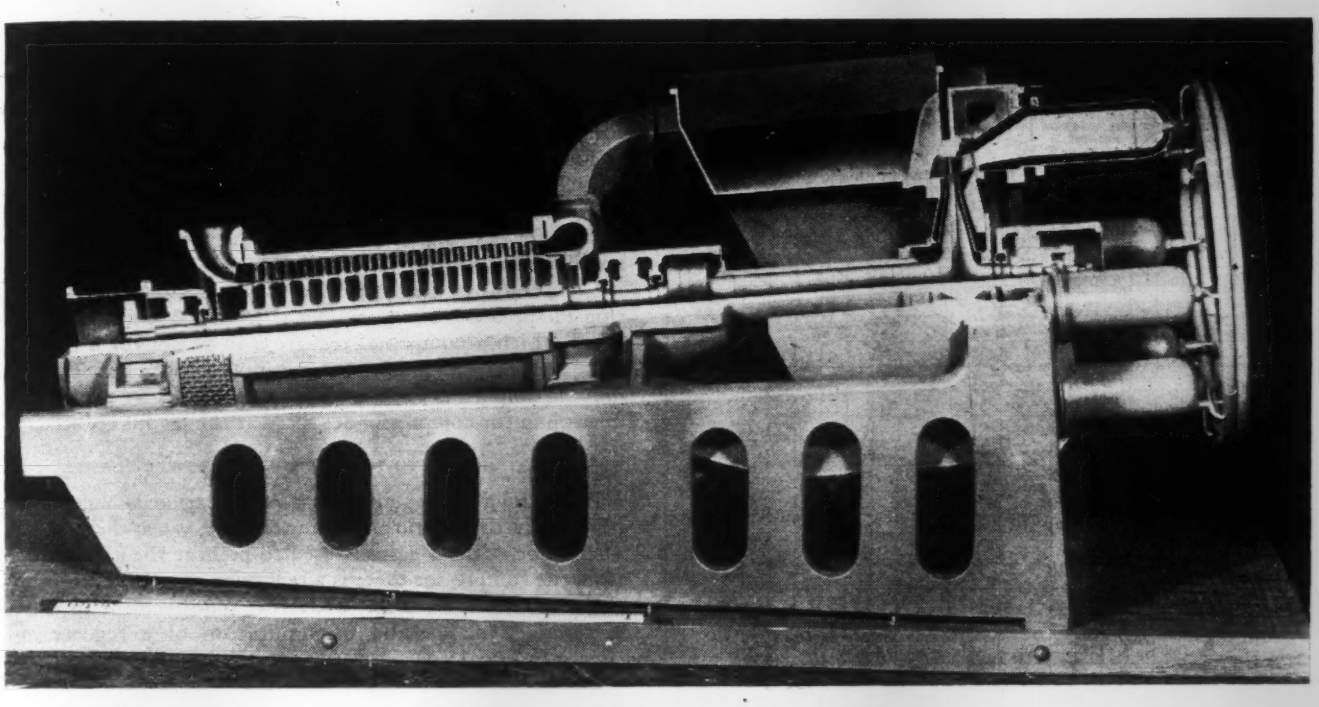


FIG. 12 CROSS SECTION OF A MARINE UNIT MODEL

plant arrangement is given in Fig. 12, which illustrates a design of a 3000-hp marine gas-turbine power plant having a single compressor and turbine unit. The multiple combustion chambers are arranged in juxtaposition to the turbine wheel itself, thus minimizing problems in transport of the high-temperature gases. Air enters the compressor at the left-hand side and, after compression, is passed through the rectangular ducts, past the exhaust hood, and into the annular space surrounding the inner liner of the combustion chambers. The latter are mounted at the end of the unit for easy accessibility in replacement if this becomes necessary. The relatively cool incoming air causes the liner to operate at a temperature considerably lower than the gas temperature. The hot gases pass immediately through an air-cooled nozzle and to the turbine buckets, thence through the exhaust hood to the atmosphere.

OPERATING CHARACTERISTICS

For illustrative purposes, the basis of nearly all of the calculated data is a nominal turbine and compressor efficiency of 80 per cent. Small variations of the efficiencies will not seriously affect the relationship of the characteristic curves in the comparison of various cycles. In most cases the cycle pressure drops have been neglected. Since pressure drop is exchangeable for compressor or turbine efficiency the fuel-consumption data presented herein would require higher efficiencies than 80 per cent in accordance with the magnitude of the cycle pressure drops. For an actual design it is, of course, essential that the minor variations, such as variable specific heat, reheat factor, presence of a small quantity of fuel, pressure drops, etc., be properly taken into account in order that the output of the machine will be as predicted. This is true to a greater extent for the gas-turbine plant than for a steam plant because of the "leverage" resulting from the large ratio of machinery power to net power, and the comparatively short energy range which is used.

Fig. 13 shows the manner in which the net output at the coupling varies as the pressure ratio (hence speed) varies, for various initial temperatures. Note the rapid decrease in power as the inlet temperature is decreased. The variation in power is approximately linear with respect to pressure ratio over part of the range. In an actual gas-turbine plant, it is

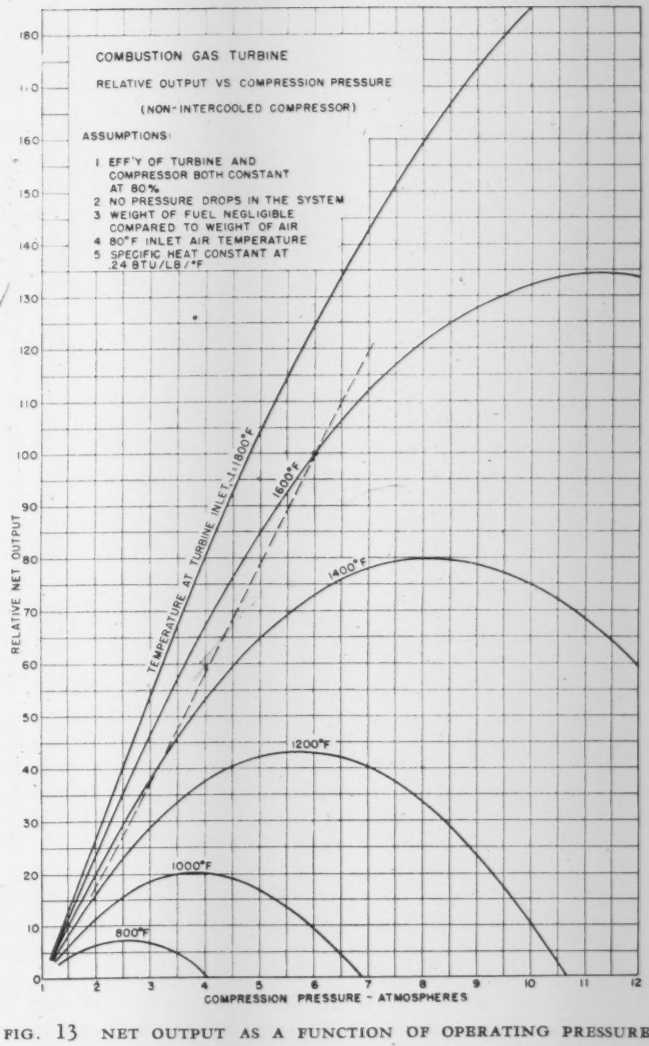


FIG. 13 NET OUTPUT AS A FUNCTION OF OPERATING PRESSURE

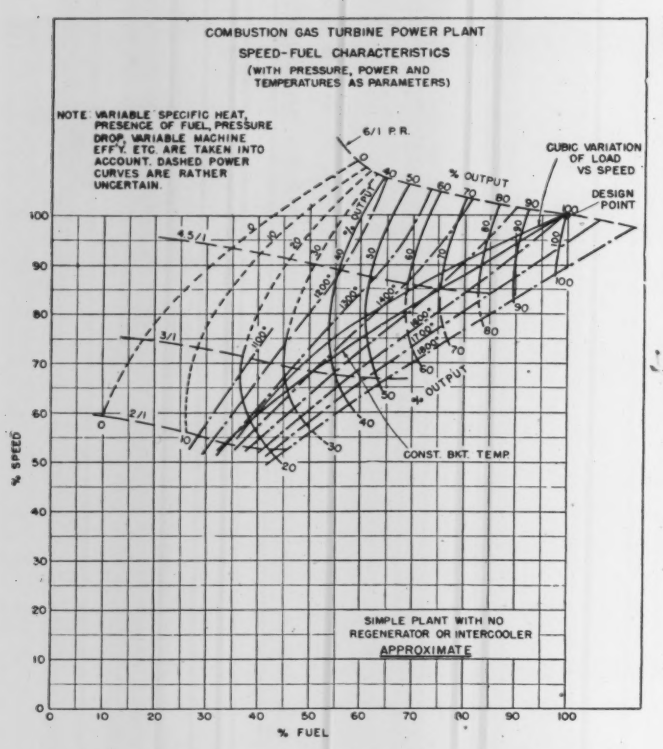

COMBUSTION GAS TURBINE POWER PLANT
SPEED-FUEL CHARACTERISTICS
(WITH PRESSURE, POWER AND TEMPERATURES AS PARAMETERS)
NOTE. VARIABLE SPECIFIC HEAT, PRESENCE OF FUEL, PRESSURE DROP, VARIABLE MACHINE EFF'Y, ETC. ARE TAKEN INTO ACCOUNT. DASHED POWER CURVES ARE RATHER UNCERTAIN.
6/1 P.R.
CUBIC VARIATION OF LOAD VS SPEED
DESIGN POINT
% OUTPUT
% STATIC
4.5/1
3/1
2/1
CONST. BKT. TEMP.
SIMPLE PLANT WITH NO REGENERATOR OR INTERCOOLER
APPROXIMATE
% SPEED
% FUEL

FIG. 14 CHARACTERISTICS OF GAS-TURBINE POWER PLANT

desirable to reduce the temperature as the speed (pressure ratio) is reduced in order that excessive bucket temperatures will not be encountered. This reduction in speed also improves the thermal performance. The actual operation curve would, in Fig. 13, cut across the various temperature lines as the pressure ratio is decreased, in the manner indicated by the dash line.

Many variables are involved in the study of the gas-turbine power plant. Oddly enough, this simplest of all power plants offers so many alternative methods of operation that a clear conception of the interrelationship of all of the variables is rather difficult to obtain. In fact it is nearly impossible to present a clear, concise, graphical picture of *all* of these variables in simple form.

The gas-turbine power plant in operation can be affected externally only by change of the fuel supplied or of the speed. The former can be controlled automatically or otherwise through a fuel pump or throttle valve, while the latter is controlled by the character of the load applied to the gas-turbine coupling. These two variables, that is, speed and fuel, therefore represent the most logical ones against which to illustrate the characteristics of the power plant.

In Fig. 14 are pictured the more important characteristics plotted with parameters on a speed-fuel plane. The data take into account all of the minor variables, such as variable specific heat for the true gas composition, pressure drops, weight flow of fuel, variable machine efficiency, etc. The nearly vertical curved lines in Fig. 14 are lines of constant output. The dash-dot lines are lines of constant turbine-inlet temperature, and the dash lines are lines of constant pressure ratio.

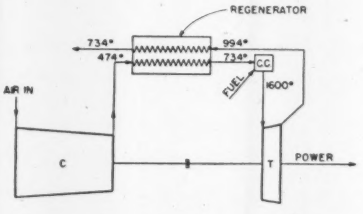
Note that a given power output can be obtained at several combinations of conditions; for example, 100 per cent output can be obtained with either 6:1 pressure ratio and 1600 F inlet temperature, or with about 5:1 pressure ratio and about 1800 F temperature. If the latter combination is used, the fuel consumed is about 97.5 per cent of the design fuel consumption, and the speed is approximately 88 per cent of the design speed. It will be noted that a unit operating at 50 per cent power and at 100 per cent design speed consumes more fuel than the same unit would consume if its speed were reduced to about 80 per cent of the design speed. Thus there is a sacrifice in economy when the gas-turbine unit is operated at constant speed and reduced load. The locus of the conditions of operation for best fuel economy is a line passing through the points at the extreme left on the constant-power curves. Such a locus corresponds very nearly to the line which represents operation at constant bucket temperature.

Study of these data indicates the particularly favorable relationship between the power-speed characteristic of the gas turbine for best fuel economy, and that encountered in marine applications. As the power is reduced, a reduction in speed is required if best fuel economy is to be obtained. This reduction in speed is very nearly equal to the natural reduction in speed which accompanies reduction in power for a propeller-driven ship. Obviously, in any application where fuel economy is important, some provision should be made for reduction in the compressor-set speed as the load is reduced.

ADDITIONS TO THE GAS-TURBINE POWER PLANT

It has long been known that regeneration is extremely efficacious in the gas-turbine plant because, when the waste heat of the hot exhaust gases is used to preheat the air discharged from the compressor there is a reduction in the fuel required in the combustion chamber, and great improvement in the fuel economy. The method of application of a regenerator is shown in Fig. 15.

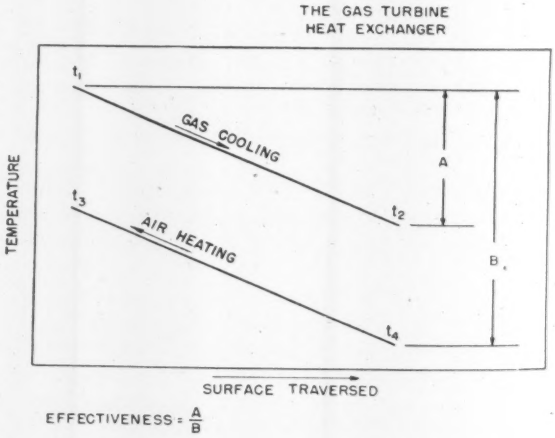
The term "effectiveness" has come to be used in connection



REDUCTION IN FUEL CONSUMPTION: $\frac{734°-474°}{1600°-474°} \times \frac{260°}{1126°} = 23\%$ APPROXIMATELY

(ABOVE FIGURES BASED ON 5:1 PRESSURE RATIO)

FIG. 15 THE GAS-TURBINE REGENERATOR



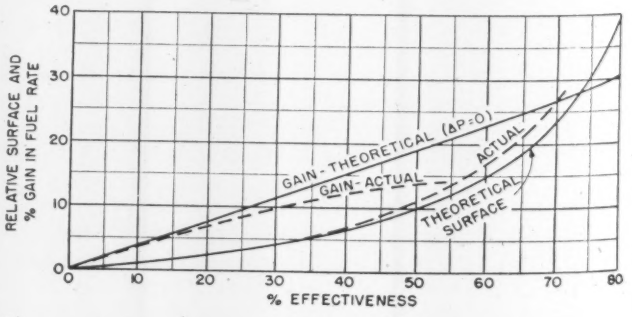


FIG. 16 REGENERATOR EFFECTIVENESS AND GAIN

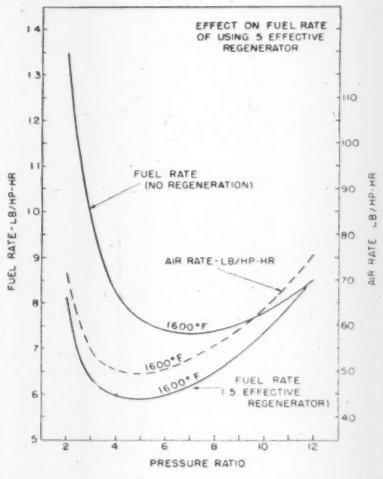
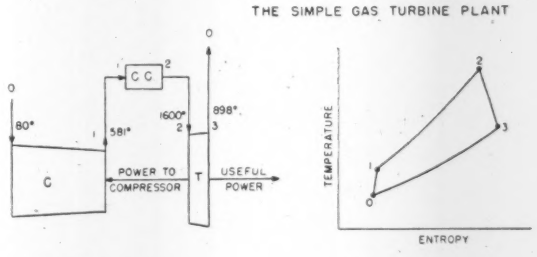
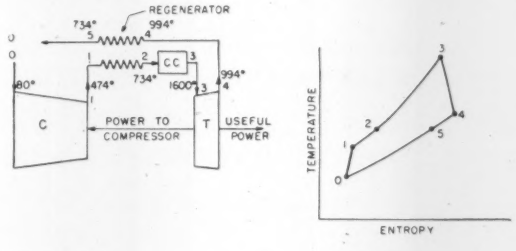


FIG. 17 EFFECT OF A REGENERATOR ON FUEL RATE



ASSUMPTIONS	RESULTS	
1. $\eta_t = \eta_c = 80\%$	BEST PRESSURE RATIO	7:1
2. 18,500 BTU/LB FUEL OIL	FUEL RATE	.73 LB OIL/HP-HR
3. CONSTANT SPECIFIC HEAT	THERMAL EFFICIENCY	18.8%
4. NO PRESSURE DROPS	AIR RATE	52.8 LB/HP-HR
5. NO MECHANICAL LOSSES	GROSS/NET POWER	3.49 HP/HP
6. 1600° F THROTTLE TEMP	BUCKET TEMP	1075°F

FIG. 18 DATA FOR SIMPLE PLANT



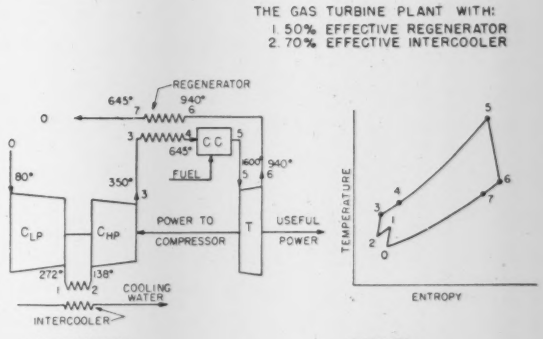
ASSUMPTIONS	RESULTS	
1. $\eta_t = \eta_c = 80\%$	BEST PRESSURE RATIO	5:1
2. 18,500 BTU/LB FUEL OIL	FUEL RATE	.59 LB OIL/HP-HR
3. CONSTANT SPECIFIC HEAT	THERMAL EFFICIENCY	23.4%
4. NO PRESSURE DROPS	AIR RATE	50 LB/HP-HR
5. NO MECHANICAL LOSSES	GROSS/NET POWER	2.75 HP/HP
6. 1600° F THROTTLE TEMP	BUCKET TEMP	1150°F

FIG. 19 DATA FOR REGENERATIVE PLANT

with regeneration. This term is defined by the diagram shown in Fig. 16. Fig. 16 also shows the theoretical gain at rated load for a power plant designed with 6 atm compressor-discharge pressure and 1600 F turbine-inlet temperature. The linearity of the gain with effectiveness justifies the use of the term. The actual gain is somewhat less than shown by the solid line because of the pressure drops incident to gas passage through the regenerator.[2] The surface, weight, and cost of a regenerator increase rapidly as the effectiveness increases, hence an economic problem arises in the choice of the regenerator effectiveness.

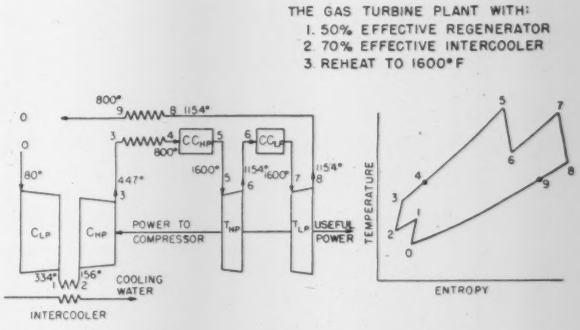
The regenerator causes a reduction of the fuel rate, as shown in Fig. 17, and a displacement of the lowest point of the fuel-rate curve to a lower pressure ratio than for the simple non-regenerative plant. Fig. 17 illustrates the air rate obtained in a plant for various design conditions, assuming no pressure drop in the regenerator. Note that the optimum fuel rate is obtained at the lowest air rate when a regenerator is used, whereas this is not so for the simple plant. The air-rate curve is identical for both plants if no pressure drops exist.

Figs. 18, 19, 20, and 21, respectively, illustrate data calculated for (1) the simple plant; (2) the regenerative plant; (3) the intercooled regenerative plant; (4) the intercooled regenerative plant with reheat.



ASSUMPTIONS	RESULTS	
1. $\eta_t = \eta_c = 80\%$	BEST PRESSURE RATIO	6:1
2. 18,500 BTU/LB FUEL OIL	FUEL RATE	.54 LB OIL/HP-HR
3. CONSTANT SPECIFIC HEAT	THERMAL EFFICIENCY	25.5%
4. NO PRESSURE DROPS	AIR RATE	41.3 LB/HP-HR
5. NO MECHANICAL LOSSES	GROSS/NET POWER	2.57 HP/HP
6. 1600° F THROTTLE TEMP	BUCKET TEMP	1100°F

FIG. 20 DATA FOR INTERCOOLED REGENERATIVE PLANT



ASSUMPTIONS	RESULTS	
1. $\eta_t = \eta_c = 80\%$	BEST PRESSURE RATIO	10:1
2. 18,500 BTU/LB FUEL OIL	FUEL RATE	52 LB OIL HP-HR
3. CONSTANT SPECIFIC HEAT	THERMAL EFFICIENCY	26.5%
4. NO PRESSURE DROPS	AIR RATE	30.6 LB/HP-HR
5. NO MECHANICAL LOSSES	GROSS/NET POWER	2.57 HP/HP
6. 1600° F THROTTLE TEMP	BUCKET TEMP	1260° F

FIG. 21 DATA FOR INTERCOOLED REGENERATIVE PLANT WITH REHEAT

COMPARISON OF CYCLES, EACH AT 1600°F AND ITS OPTIMUM PRESSURE RATIO

ITEM	SIMPLE	50% REGENERATOR†	70% INTERCOOLER†	REHEAT TO 1600°
OPTIMUM PR RATIO	7:1	5:1	6:1	10:1
FUEL RATE	.73	.59	.54	.52
GAIN-%	–	19	8.5	3.7
THERMAL EFF'Y	18.8	23.4	25.5	26.5
AIR RATE	52.8	50	41.3	30.6
RELATIVE RPM†	100	103	113	–
GROSS/NET POWER	3.49	2.75	2.57	2.57
BUCKET TEMP	1075°	1150°	1100°	1260°

†AS DETERMINED BY COMPRESSOR DESIGN

FIG. 22 COMPARISON OF DATA FOR VARIOUS PLANTS

[2] The loss in fuel rate caused by a pressure drop of 1 per cent in modern gas-turbine cycles may be from 10 to 20 times as much as that caused by 1 per cent pressure drop in a modern steam plant. This fact emphasizes the necessity for careful design of gas and air passages.

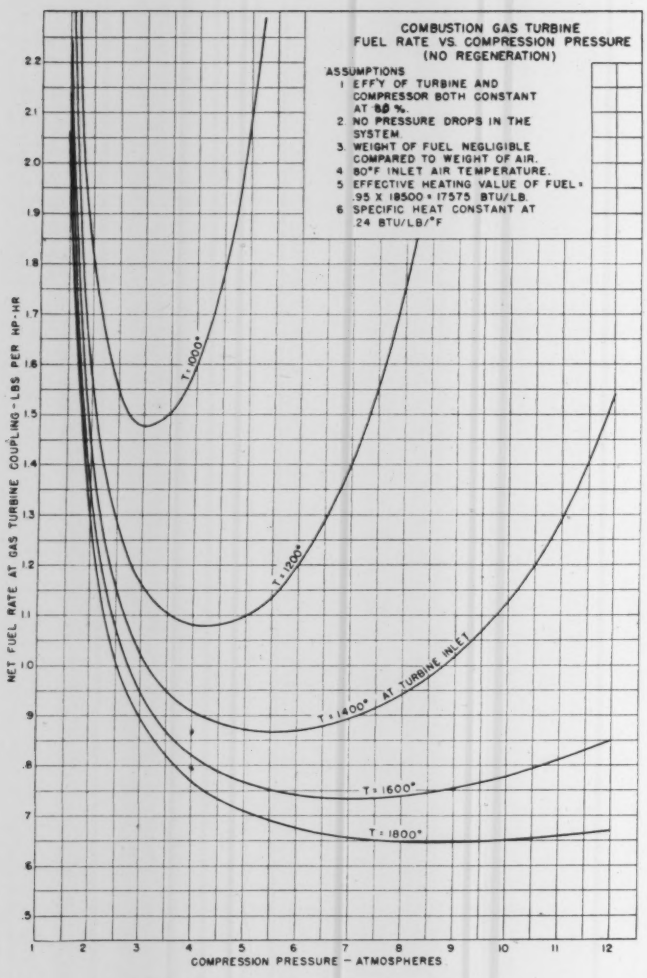

COMBUSTION GAS TURBINE
FUEL RATE VS. COMPRESSION PRESSURE
(NO REGENERATION)
ASSUMPTIONS
1 EFFY OF TURBINE AND COMPRESSOR BOTH CONSTANT AT 80 %.
2 NO PRESSURE DROPS IN THE SYSTEM.
3 WEIGHT OF FUEL NEGLIGIBLE COMPARED TO WEIGHT OF AIR.
4 80°F INLET AIR TEMPERATURE.
5 EFFECTIVE HEATING VALUE OF FUEL = .95 X 18500 = 17575 BTU/LB.
6 SPECIFIC HEAT CONSTANT AT .24 BTU/LB/°F
T=1000°
T=1200°
T=1400° AT TURBINE INLET
T=1600°
T=1800°
NET FUEL RATE AT GAS TURBINE COUPLING - LBS PER HP-HR
COMPRESSION PRESSURE - ATMOSPHERES

FIG. 23 FUEL RATE OF SIMPLE PLANT

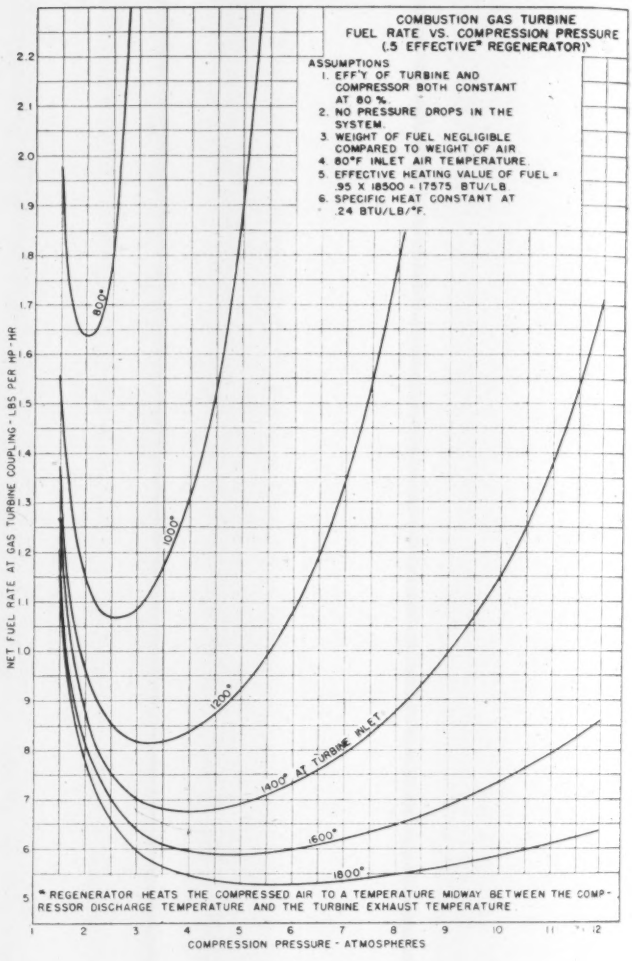

COMBUSTION GAS TURBINE
FUEL RATE VS. COMPRESSION PRESSURE
(.5 EFFECTIVE* REGENERATOR)*
ASSUMPTIONS
1. EFFY OF TURBINE AND COMPRESSOR BOTH CONSTANT AT 80 %.
2. NO PRESSURE DROPS IN THE SYSTEM.
3. WEIGHT OF FUEL NEGLIGIBLE COMPARED TO WEIGHT OF AIR
4 80°F INLET AIR TEMPERATURE
5. EFFECTIVE HEATING VALUE OF FUEL = .95 X 18500 = 17575 BTU/LB
6. SPECIFIC HEAT CONSTANT AT .24 BTU/LB/°F.
800°
1000°
1200°
1400° AT TURBINE INLET
1600°
1800°
* REGENERATOR HEATS THE COMPRESSED AIR TO A TEMPERATURE MIDWAY BETWEEN THE COMPRESSOR DISCHARGE TEMPERATURE AND THE TURBINE EXHAUST TEMPERATURE
NET FUEL RATE AT GAS TURBINE COUPLING - LBS PER HP-HR
COMPRESSION PRESSURE - ATMOSPHERES

FIG. 24 FUEL RATE OF REGENERATIVE PLANT

All of the data assume a turbine and compressor efficiency of 80 per cent, constant specific heat, and 1600 F turbine-inlet temperature. Fig. 22 tabulates the data shown in Figs. 18 to 21, inclusive, and compares the thermal efficiencies, air rates, etc.

These diagrams are presented to illustrate the progressive effect of adding supplementary equipment to the basic plant, eliminating the pressure ratio as a possible variable by using, in each case, the optimum value, and the temperature by using 1600 F for all cycles.

There is a decrease in the value of the optimum pressure ratio when regeneration is used, and an increase when an intercooler or reheat is used. Thus the optimum value of 7:1 for a simple plant becomes 5:1, when a regenerator is used; it increases to 6:1, when an intercooler is used; and it increases further to about 10:1, when reheat is added.

The relative speeds shown in Fig. 22 have a direct influence upon the size of the plant, since higher design speed permits smaller diameters. At the same time, the higher pressure ratio tends to increase the compressor length for a given design, and must be considered as an offsetting factor in so far as plant size is concerned.

FUEL ECONOMY

Figs. 23, 24, and 25 illustrate, respectively, fuel rates calculated (1) for the simple gas-turbine power plant; (2) the regenerative plant; (3) the intercooled regenerative plant with reheat.

These curves illustrate the shifting of the pressure at which best fuel economy is obtained, as the temperature increases. Notable is the shifting to the left of the entire set of curves for the regenerative plant over the simple plant. Note also that the gains resulting from reheat are not nearly as great as those which result from regeneration. If we are to illustrate the gains due to reheat and intercooling *only*, it is essential that the turbine and compressor efficiencies be adjusted over the previous values, in order that the extraneous gain, resulting from the expansion and compression occurring in two steps, be eliminated. This has been done in Fig. 25, as recorded in assumption (1).

It is impossible to predict what is likely to happen in the future development of the gas-turbine power plant. We can, however, calculate the effects of increased machine efficiency and turbine-inlet temperature on the fuel rates of the regenerative plant. Shown in Fig. 26 is a plot of the optimum fuel rate against machine efficiency for various throttle temperatures. These curves represent "best" fuel rates in the sense that they are all taken at the optimum pressure ratio for the efficiency and temperature used. The best pressure ratios are shown by the figures on the curves. These data are extremely significant in that they indicate potentialities in the regions beyond today's designs and include allowance for pressure drops, auxiliaries, and other factors affecting the performance of the prime-mover plant.

APPLICATION OF THE GAS-TURBINE POWER PLANT

In considering the possible applications of the gas-turbine power plant, one of the first questions likely to arise in the mind of the engineer is: "How does its efficiency compare with other prime movers?" Fig. 27 shows a comparison of the fuel rates of a gas-turbine power plant (designed for 6 atm pressure and 1600 F temperature) with steam plants and a Büchi

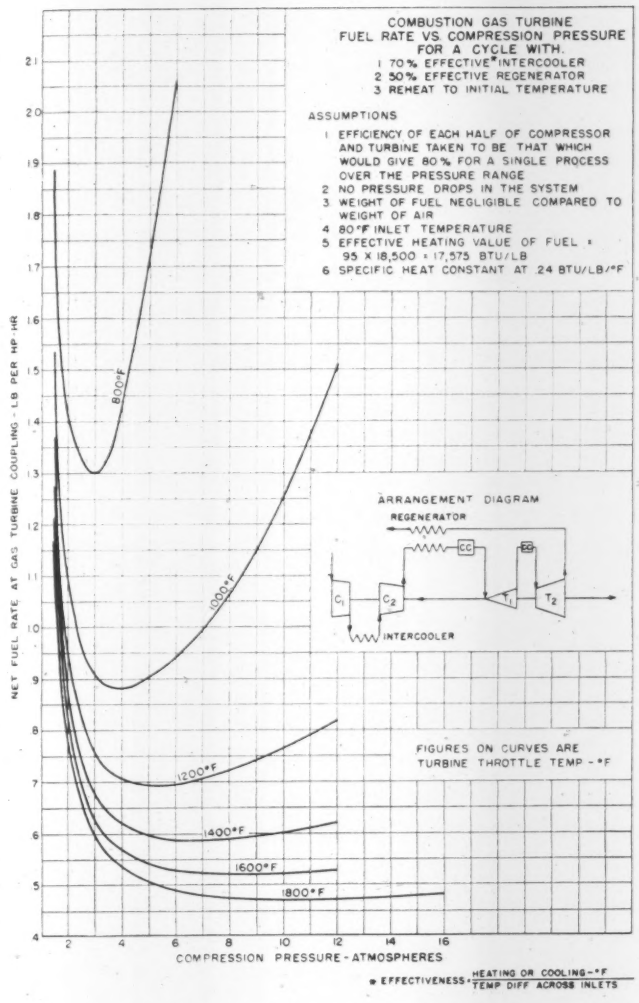

COMBUSTION GAS TURBINE
FUEL RATE VS. COMPRESSION PRESSURE
FOR A CYCLE WITH.
1 70% EFFECTIVE* INTERCOOLER
2 50% EFFECTIVE REGENERATOR
3 REHEAT TO INITIAL TEMPERATURE
ASSUMPTIONS
1 EFFICIENCY OF EACH HALF OF COMPRESSOR AND TURBINE TAKEN TO BE THAT WHICH WOULD GIVE 80% FOR A SINGLE PROCESS OVER THE PRESSURE RANGE
2 NO PRESSURE DROPS IN THE SYSTEM
3 WEIGHT OF FUEL NEGLIGIBLE COMPARED TO WEIGHT OF AIR
4 80°F INLET TEMPERATURE
5 EFFECTIVE HEATING VALUE OF FUEL = 95 X 18,500 = 17,575 BTU/LB
6 SPECIFIC HEAT CONSTANT AT .24 BTU/LB/°F
ARRANGEMENT DIAGRAM
REGENERATOR
CC
EC
C1
C2
T1
T2
INTERCOOLER
800°F
1000°F
1200°F
1400°F
1600°F
1800°F
FIGURES ON CURVES ARE TURBINE THROTTLE TEMP - °F
NET FUEL RATE AT GAS TURBINE COUPLING - LB PER HP-HR
COMPRESSION PRESSURE - ATMOSPHERES
* EFFECTIVENESS = HEATING OR COOLING - °F / TEMP DIFF ACROSS INLETS

FIG. 25 FUEL RATE OF INTERCOOLED REGENERATIVE PLANT WITH REHEAT

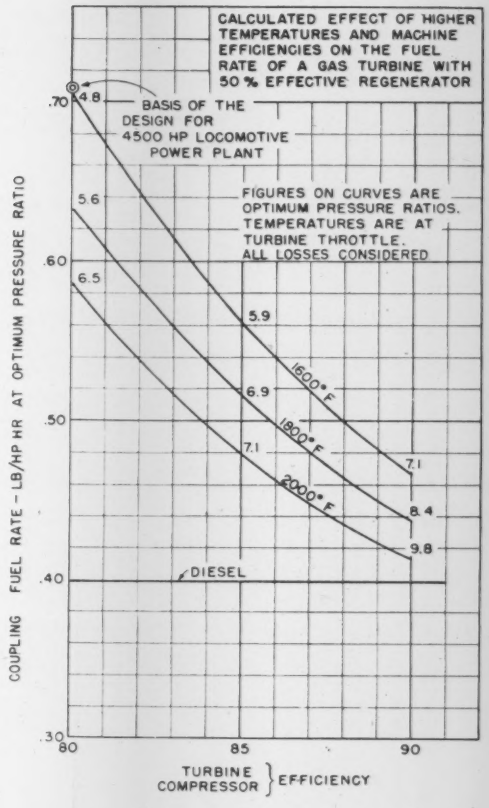


FIG. 26 EFFECT ON FUEL RATE OF HIGHER EFFICIENCY AND TEMPERATURE

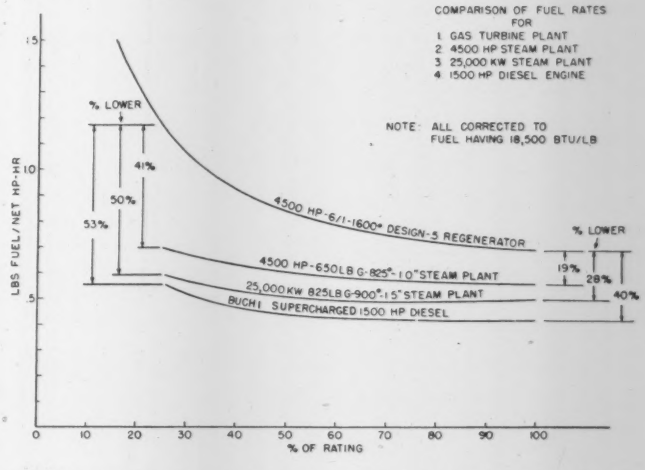


FIG. 27 COMPARISON OF GAS-TURBINE, STEAM, AND DIESEL PLANTS

supercharged Diesel, all corrected to the same fuel heating value. It must be emphasized that again purely arbitrary values of compressor and turbine efficiencies have been chosen, namely, 80 per cent at rated load. Pressure drops and auxiliary power have been taken into account. Increase of the efficiency level will rapidly reduce the fuel rate, as clearly indicated in Fig. 26. For these assumptions, Fig. 27 indicates that both the steam plant and the Diesel exceed the gas-turbine plant in over-all fuel economy. It must be remembered, however, that the present gas-turbine power plant has as its chief virtue, not good fuel economy, but rather simplicity, compactness, lightness of weight, and an almost complete absence of auxiliaries. In these it has no peer.

Although the Diesel on first glance appears to be outstanding among the plants shown, several facts must be considered. While some Diesel plants have been and are operating on the heavier and cheaper fuel oils, by far the greater proportion of the users prefer to use the higher-grade ash-free Diesel fuel intended specifically for these engines. This fuel costs 50 to 75 per cent more per heat unit than the Bunker C fuel used in most oil-fired steam plants, and $3\frac{1}{2}$ to 4 times as much per heat unit as coal. This cost, together with the lubricating-oil costs (which may be from 5 to 10 per cent of the fuel cost) tend in great measure to offset the low fuel consumption. The best steam plants will equal the Diesel's fuel consumption, but it must be remembered that in most cases they use low-cost coal and have a very low lubricating-oil consumption.

The gas-turbine plant seems to have more potentialities as a coal burner than the Diesel. Actually neither is yet operating commercially in this country on coal, and some of the European efforts at burning coal in a reciprocating engine have been abandoned as not too promising. If the gas-turbine plant *can* be operated on coal its rather modest thermal efficiency can be converted into an excellent dollar efficiency.

As previously mentioned, the gas turbine, in some respects, is well adapted to marine application. Fig. 28 illustrates a model of a 3000-hp gas-turbine power plant designed for marine use. This model is of a plant which did not include a regenerator. Fig. 29 illustrates a similar marine unit, designed with a regenerator of 50 per cent effectiveness. There is considerable increase in the physical size of the second unit over the first, but also an appreciable improvement in fuel economy.

Provision must be made for maneuvering and astern operation in marine applications. For direct-current electric drive,

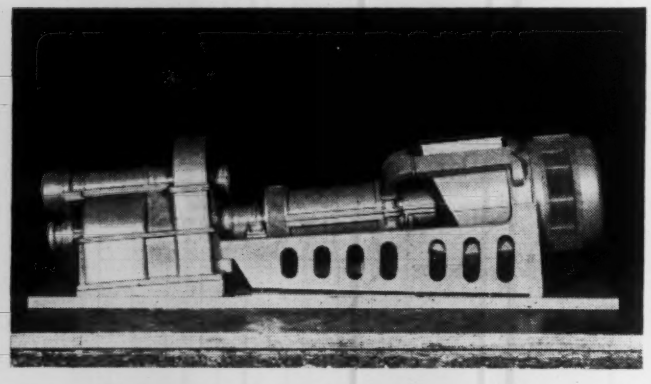


FIG. 28 MODEL OF A MARINE UNIT DESIGN

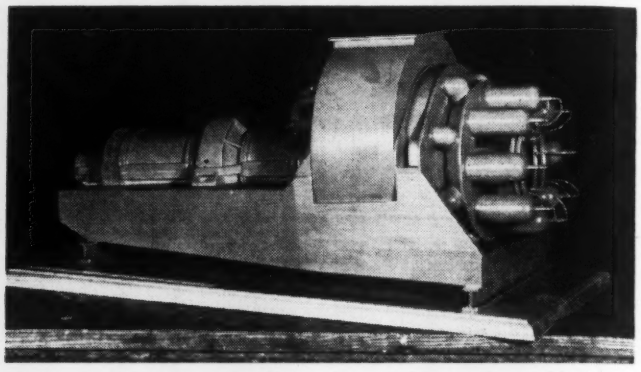


FIG. 29 MODEL OF A MARINE UNIT DESIGN WITH REGENERATOR

the high torque requirements at the time of reversing can be met by maintaining nearly full speed on the set. Reversing can, of course, be accomplished electrically. Another very-promising arrangement for marine applications is the variable-pitch or, preferably, the reversible-pitch propeller. Use of this device permits independent control of the gas-turbine-set speed, thus allowing the operator to obtain best thermal performance from the gas-turbine set at all times, and greatly facilitating the maneuvering problem.

A question is often raised as to the applicability of the gas-turbine power plant for central-station power. Where fuel economy is of paramount importance, it is obvious that the oil-burning gas-turbine plant is not, in its present state of development, competitive, except in special cases such as where lack of water, cheap fuel, etc., make it attractive. It is attractive as a stand-by plant, such as the Neuchatel bombproof plant constructed in Switzerland because of low fixed charges, quick starting ability, and its small space requirement. When operated at the constant speed required in central-station use, the fuel economy of a single-shaft unit is not as good as when the speed can be reduced. This was illustrated in Fig. 14. The large volumes of air required tend to limit the rating of gas turbines to values which are lower than present steam turbines by rather wide margins The gas turbine is usually considered not to be a competitor of the large efficient steam

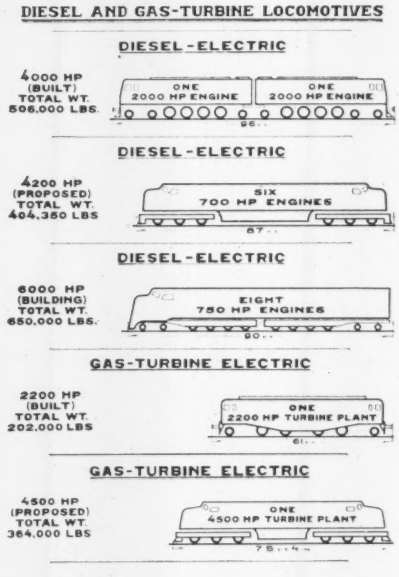

DIESEL AND GAS-TURBINE LOCOMOTIVES
DIESEL-ELECTRIC
4000 HP (BUILT) TOTAL WT. 506,000 LBS.
ONE 2000 HP ENGINE
ONE 2000 HP ENGINE
DIESEL-ELECTRIC
4200 HP (PROPOSED) TOTAL WT. 404,350 LBS
SIX 700 HP ENGINES
DIESEL-ELECTRIC
6000 HP (BUILDING) TOTAL WT. 650,000 LBS.
EIGHT 750 HP ENGINES
GAS-TURBINE ELECTRIC
2200 HP (BUILT) TOTAL WT. 202,000 LBS
ONE 2200 HP TURBINE PLANT
GAS-TURBINE ELECTRIC
4500 HP (PROPOSED) TOTAL WT. 364,000 LBS
ONE 4500 HP TURBINE PLANT

FIG. 30 DIESEL AND GAS-TURBINE LOCOMOTIVES

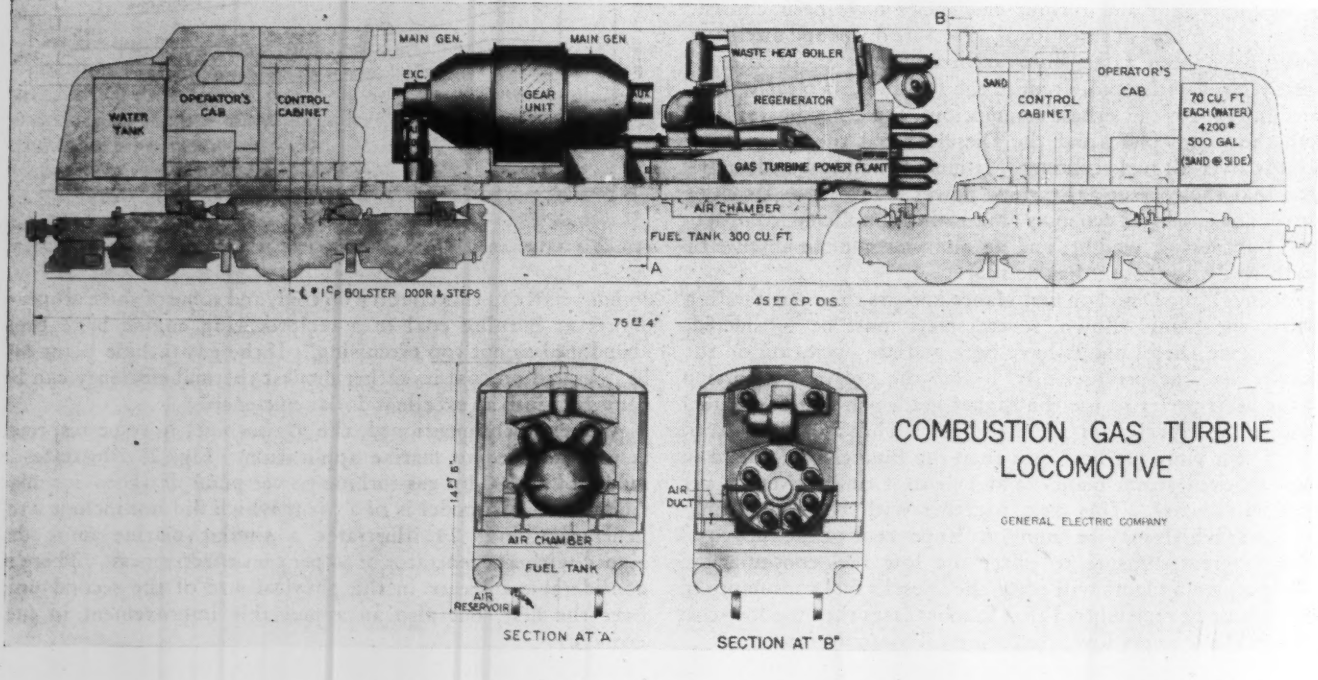


FIG. 31 GENERAL ELECTRIC GAS-TURBINE-LOCOMOTIVE DESIGN

plant, but rather as complementary, in its position as a reliable simple prime mover of intermediate capacity.

The experience of the present war has indicated that the future range of size required for aircraft engines may be from 2000 to 8000 hp. Since cooling water is not available in aircraft use without large radiators, the steam plant, which is essentially heavy anyway, is probably not of too much significance. The lightweight internal-combustion engine seems to be approaching a rather definite limit in rating. The gas turbine on the other hand just comes into its own in the sizes at which the gasoline engine seems to be approaching a limit. Furthermore, it does not require expensive high-octane fuel for its operation. It is quite apparent to any thoughtful engineer, therefore, that one potential field for gas-turbine application is in the postwar cargo- and transport-plane field.

Another extremely fertile field for exploitation of this new prime mover is in land transportation. The Swiss Federated Railways already have in operation a 2200-hp gas-turbine locomotive. This locomotive and several Diesel locomotives of a developmental nature are shown in Fig. 30. All of the outlines are to the same scale. The Swiss locomotive power plant was designed with rather modest operating conditions and has shown in actual operation, with varying load, etc., a thermal efficiency of about 11.4 per cent. Although this efficiency is not remarkable in ordinary practice it is quite high when compared with the reciprocating steam locomotive which has long occupied the attention of locomotive builders.

The author s company has recognized the particular adaptability of the gas-turbine plant to locomotive design and has made rather extensive studies of a 4500-hp locomotive using a single gas-turbine unit (with a regenerator and waste-heat boiler) as the motive-power source. The thermal efficiency of this locomotive, its ease of assembly, accessibility, lightness of weight and smooth flow of power, all indicate that it is an attractive application. The bottom diagram in Fig. 30 is an outline of the gas-turbine-powered locomotive.

This locomotive features a 4500-hp oil-burning power plant in a single cab. All axles are motored, and the power per ton of weight is considerably higher than an equivalent locomotive employing other prime movers. All equipment is accessible, despite the use of a regenerator for fuel-economy reasons. A phantom view of the locomotive and its machinery is presented in Fig. 31.

The waste-heat boiler, mounted above the regenerator, serves, when equipped with separate firing, to start the gas-turbine plant by supplying steam to the gas-turbine wheel. It can also generate train-heating steam on waste heat, in passenger service, or be used for a power "boost" in freight service, under special conditions. The gas-turbine plant is geared, through double-reduction gearing, to two tandem-mounted direct-current generators, which permit speed control of the gas-turbine plant for best fuel economy. Another feature of the gas-turbine locomotive, which has interesting possibilities for mountainous terrain, is dynamic braking. Reduction of the fuel supply causes the output of the plant to become negative. The work of air compression is then easily dissipated to the atmosphere.

Undoubtedly, the gas-turbine plant will continue to be used in various oil-refining processes, and as a supercharger for boiler furnaces. What new uses will develop as time goes on depends only upon the ingenuity of application engineers, together with the zeal and courage employed by the developmental engineers in perfecting this most recent and attractive prime mover.

RESEARCH, ENGINEERING THEORY, AND EXPERIMENTAL DESIGN PRECEDE GREAT COMMERCIAL DEVELOPMENTS—THE PICTURE SHOWS THE MODEL OF THE GENERAL ELECTRIC GAS TURBINE AND SOME OF THE DESIGNERS' TOOLS

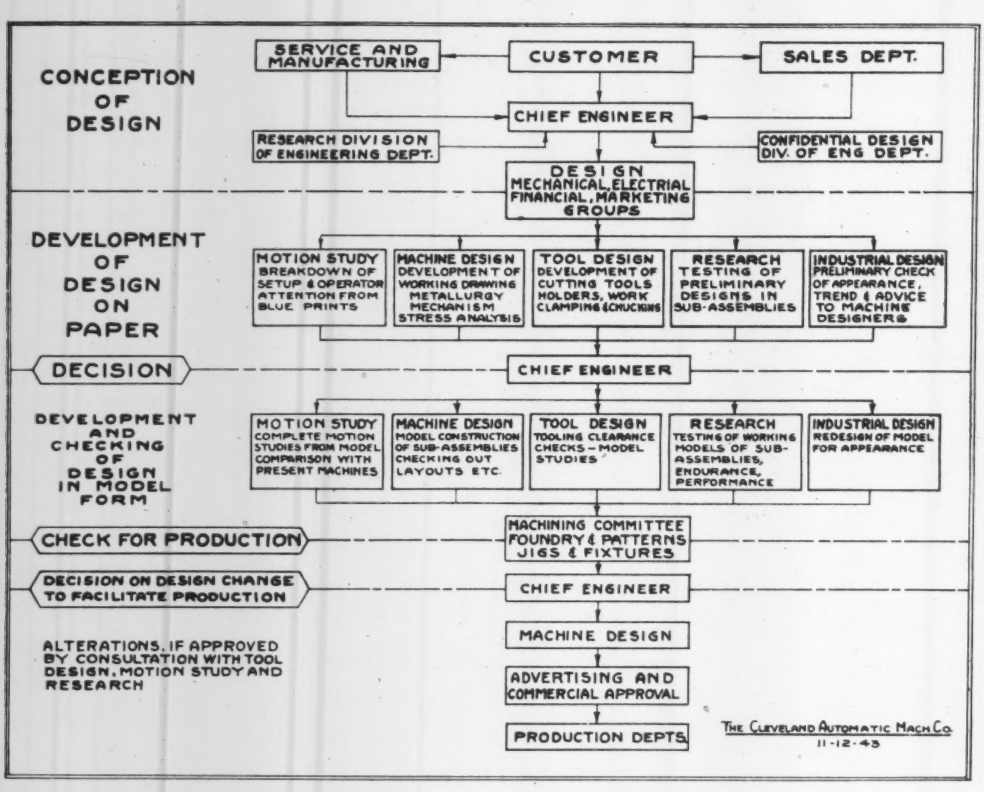

CONCEPTION OF DESIGN
SERVICE AND MANUFACTURING
CUSTOMER
SALES DEPT.
CHIEF ENGINEER
RESEARCH DIVISION OF ENGINEERING DEPT.
CONFIDENTIAL DESIGN DIV. OF ENG DEPT.
DESIGN MECHANICAL, ELECTRIAL FINANCIAL, MARKETING GROUPS
DEVELOPMENT OF DESIGN ON PAPER
MOTION STUDY BREAKDOWN OF SETUP & OPERATOR ATTENTION FROM BLUE PRINTS
MACHINE DESIGN DEVELOPMENT OF WORKING DRAWING METALLURGY MECHANISM STRESS ANALYSIS
TOOL DESIGN DEVELOPMENT OF CUTTING TOOLS HOLDERS, WORK CLAMPING & CHUCKING
RESEARCH TESTING OF PRELIMINARY DESIGNS IN SUB-ASSEMBLIES
INDUSTRIAL DESIGN PRELIMINARY CHECK OF APPEARANCE, TREND & ADVICE TO MACHINE DESIGNERS
DECISION
CHIEF ENGINEER
DEVELOPMENT AND CHECKING OF DESIGN IN MODEL FORM
MOTION STUDY COMPLETE MOTION STUDIES FROM MODEL COMPARISON WITH PRESENT MACHINES
MACHINE DESIGN MODEL CONSTRUCTION OF SUB-ASSEMBLIES CHECKING OUT LAYOUTS ETC.
TOOL DESIGN TOOLING CLEARANCE CHECKS - MODEL STUDIES
RESEARCH TESTING OF WORKING MODELS OF SUB-ASSEMBLIES, ENDURANCE, PERFORMANCE
INDUSTRIAL DESIGN REDESIGN OF MODEL FOR APPEARANCE
CHECK FOR PRODUCTION
MACHINING COMMITTEE FOUNDRY & PATTERNS JIGS & FIXTURES
DECISION ON DESIGN CHANGE TO FACILITATE PRODUCTION
CHIEF ENGINEER
ALTERATIONS, IF APPROVED BY CONSULTATION WITH TOOL DESIGN, MOTION STUDY AND RESEARCH
MACHINE DESIGN
ADVERTISING AND COMMERCIAL APPROVAL
PRODUCTION DEPTS.
THE CLEVELAND AUTOMATIC MACH CO.
11-12-43

FIG. 1 ENGINEERING ORGANIZATION CHART; NEW-DESIGN PROCEDURE

Predicting MACHINE PRODUCTIVITY *for Future Applications*

By G. B. CARSON[1] and L. C. COLE[2]

ABOUT ten years ago, a wave of streamlining and industrial design struck the machine-tool industry. The need for better appearance in many of the machines being manufactured was forcefully called to attention by the aspect of a few machines which had been "styled." Machinery not so treated was looked upon as obsolete or out of date.

As a result, there was a tendency to rush headlong into industrial design or "styling," which frequently increased the cost of machine construction, and more frequently increased the difficulty of setup, operation, and maintenance.

Experience in the field by some manufacturers pointed to the fact that in many cases the design changes, aimed at increasing the capacity or range of a machine, had, in fact, limited its economical use to extremely large or long-run jobs, and had, as far as the customer was concerned, increased the difficulty of finding jobs to which the machine or equipment could be applied with profit.

The coming of war production increased job sizes, so that set-up time became less of a factor, but it was soon recognized that "production rates" on machines were misleading figures to use in estimating factory output. Government and producer alike viewed so-called machine down-time with increasing alarm, because of the fact that total production, divided by total time on an assigned job, gave a figure far below the production rate which could be guaranteed for an equipment *when it was producing.*

This drop in productivity with down-time is an elementary relationship well known to everyone in the profession of production engineering.

The manufacturer of machinery and equipment was inclined to look with apprehension upon the cold fact that in his zeal to produce a faster, more flexible machine, design changes not helpful to setup, adjustment, and maintenance had crept in. It is therefore apparent that the need exists for a reasonably accurate method of predicting qualitatively the effect of design changes on the production experience[3] of a machine before it is built.

PROCEDURE FOR DESIGNING PRODUCTION EQUIPMENT

The procedure used in the design of a machine, before the days of mass production, was extremely simple. The desired specifications were formulated around a part or a general type

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[2] Chief Engineer, The Cleveland Automatic Machine Company, Cleveland, Ohio. Mem. A.S.M.E.

Contributed by the Production Engineering Division and presented at the Annual Meeting, New York, N. Y., Nov. 29–Dec. 3, 1943, of The American Society of Mechanical Engineers.

[3] Parts produced, divided by total time to which the equipment or machine is assigned to a job, deducting for "out of stock," "no tools," and "power failure."

of part to be produced, and then the designer proceeded as rapidly as possible to develop a machine capable of executing the assigned job with reliability and accuracy. Appearance was no problem, since the all-important factor was a machine which would work.

Following this, appearance consciousness made its debut, so the design became a problem of both mechanical workability and of art.

Finally, the necessity for a machine which not only would have inbuilt accuracy, reliability, and appearance, but also ease of operation and simplification of setup, became apparent. To design this new machine required an entirely new procedure which is charted in Fig. 1.

The four functional subdivisions of production-design procedure, i.e., (1) machine design, (2) tool design, (3) research, and (4) industrial design, are conventional. But it is unique, if not new, to add what might be termed the fifth sense of design, "motion study," to the procedure for designing production machines.

Referring again to Fig. 1, the chart shows four major subdivisions:

1 Conception of the design and check on financial soundness.
2 Development of design in the form of plans, layouts, and sketches.
3 Development of design in models, and working models of component parts (or the construction of a pilot model).
4 The alteration of designs to facilitate production.

The first section of the chart (conception of design) indicates that the idea comes from the office of chief engineer. In addition to his own contributions, ideas are obtained from the customer or user of the equipment, and from the company sales and service personnel. Also, ideas are received by the chief engineer from the confidential design staff and the research laboratory.

After the basic ideas have been critically examined and correlated they progress from the chief engineer to a special "group" or committee of technical and managerial personnel, through whose combined efforts the design is cleared for functional working, from the standpoint of engineering and marketing.

The unusual element in the procedure is the inclusion of motion study or "methods engineering" in the early paper stages of the design. This important part of the functional organization which is engaged in developing the design is new to most machinery or equipment development procedures. It is regarded by the authors' company of as great importance in the early stages of the design as stress analysis.

The inclusion of motion study is simply the extension of a well-known science beyond its usual limits. The designer has long considered the operability of his machinery or equipment in an informal and often unsystematic way, and has had to "cut and try," in order to develop a machine which was efficient from the standpoint of setup and operation.

PROCEDURE FOR MOTION STUDIES OF MACHINE DESIGNS

The primary objectives in studying designs in the preliminary and blueprint stage are (*a*) to provide the designers with reasonably accurate information on machine performance and (*b*) to provide them with a list of specific changes which can be made in the machine which will result in performance improvement. The order of operations for the motion study is as follows:

1 Take motion and time studies of "elemental" motions used by a skilled operator in setting up and operating a machine of similar design or similar purpose.
2 Break down the motion and time studies into three categories:
(*a*) "Direct" or productive elements
(*b*) "Indirect" or necessary, but unproductive elements
(*c*) "Unnecessary" elements
3 Throw out all "unnecessary" elements to eliminate the variable of operator or set-up man's skill from the study.
4 Create tables of "elemental" time data which can be used to estimate the time for similar operations on the new design.
5 Write the sequence of operations necessary for the setup and/or the operation of the proposed machine, working from layouts.
6 Subdivide the elements tabulated for the new design into similar and dissimilar categories. (Similar elements are those for which times may be taken from motion-and-time studies of old machines, while dissimilar elements require new time data to be created from the layouts.)
7 Create time values for dissimilar elements by use of elemental data, synthetically obtained.
8 Compare cycle time (setup or operation) of new design with previous design, throwing out all elements which may vary widely with operator skill and "good luck" in making an adjustment.

No discussion is necessary to clarify step 1, the taking of motion-and-time studies of elemental motions. It is a process well known to everyone.

Step 2, the breaking down of the studies, is done by classifying all movements which actually contribute directly to the

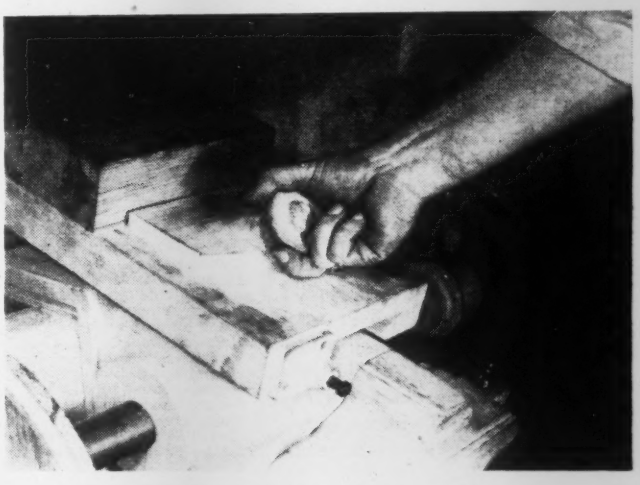

FIG. 2 HAND KNOB FOR CROSS-SLIDE ADJUSTMENT
(This is an example of a "direct" element.)

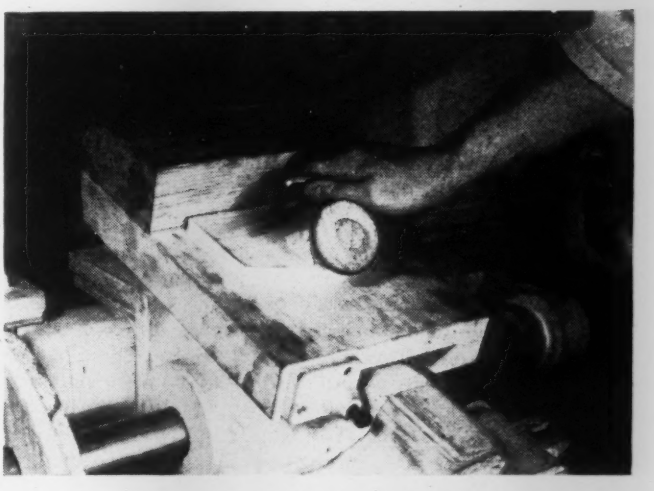

FIG. 3 CLAMPING THE CROSS-SLIDE AFTER ADJUSTMENT
(This is an example of an "indirect" element.)

desired result as "direct" elements. Fig. 2, showing a micrometer adjustment which changes the position of a tool, is an example of a direct element. In addition, however, an indirect element is necessary, i.e., that of clamping or unclamping the slide, Fig. 3, to prevent vibration from changing an adjustment. Keeping the indirect elements to a minimum both in time and number is the motion analyst's first task.

Unnecessary elements represent such items as "look for wrench," "get wrong wrench," or "drop screw-driver." The motion analyst knows that these elements vary with the skill of and system used by the operator or setup man. The motion analyst's only control is, therefore, to reduce the number of operations requiring separate tools and the number of intricate movements which may involve planning on the part of the man himself.

Since unnecessary elements are variable, depending entirely upon the operator, they should not be used in the studies. It must be assumed that unnecessary elements will be proportional to the time required to set up a machine, so that they will be somewhat higher for machines slow to set up than for those involving few operations and less time. If this assumption is correct, comparisons made will always be conservative.

Confined spaces, small clearances, and awkward working positions all tend to increase the number of "unnecessary" elements, and the time consumed by them. Simplification of a process always reduces the variable or unpredictable part of the setup job.

The tables of elementary data must be based on fundamental motions. For example, in the data taken as a basis for synthetic time values used for this study, there are such elements as get socket-head wrench; position wrench in bolt (for a given size); loosen bolt one turn. From these values, it is possible to obtain reasonably accurate predictions of the time involved in making a required adjustment as determined from studies of layouts.

When the procedure for setup is written from an analysis of the layouts, all elements considered similar to those obtained in previous studies are synthesized from such data. For all dissimilar elements, where previous times are not available, simple subassembly mock-ups are made, and time values estimated from simulated adjustments thereon.

Finally, all elements which must of necessity remain variable, such as the actual number of trial cuts required, should be thrown out of the study unless redesign provides a new method of control. Such variables as these should otherwise remain comparable for any two machines, but it is dangerous to attempt to set definite time values for them.

ANALYSIS OF MOTION STUDIES OF MACHINE DESIGNS

Table 1 is a summary of a series of studies made on a single-spindle automatic screw machine. Methods used here are equally applicable to all types of machines and production equipment. The data in the table were obtained from a combination of several standards department time studies, time studies made in plants using similar machines, and special methods studies on full-scale models in the research laboratory.

Analysis shows that, without formal study of the operator's problem, there was a worsening of the predictable elements of set-up time of 20 per cent. This should be contrasted with the 61.6 per cent saving made on the machine which was methods-engineered. The time difference of the first revision to the final design, compared to the original machine, shows an 81.6 per cent saving.

The improvements resulted from a reduction in the number of elements required of the operator and a simplification of those remaining. For example, it will be noted that the time "adjust two cross-slides" was improved by a reduction of about 64.5 per cent. This was largely accomplished by the elimination of wrench or tool changes necessary in the cam mechanism.

An intangible benefit (not measured) is the elimination of worker thought and analysis required in the cam-changing operation. Wherever worker planning is required, wide variations occur in setup time. The elimination of the necessity for such planning, therefore, renders machine setup time much more predictable, and estimated machine-productivity rates much more reliable.

A further benefit is the elimination of the number of tools required, which always results in less machine down-time while the operator searches for misplaced tools. Even in well-organized shops, unnecessary "searching elements" are frequently found in machine setup studies.

TABLE 1 MACHINE HANDLING-TIME VALUES FOR AUTOMATIC-SCREW-MACHINE SETUP[a]

Elements of setup	Time values for motion studies of machine setup, (minutes) Old model	First revision	Second revision	Third revision
Change collet chuck	6.1	4.4	4.4	1.3
Change feed fingers	5.3	3.8	3.8	3.6
Adjust stock feed	2.3	1.6	0.4	0.9
Adjust chuck tension	2.3	1.4	1.2	0.6
Change spindle speed gear	4.6	8.6	1.9	2.6
Adjust two cross slides	13.8	13.8	4.9	4.9
Adjust feed cams	6.3	9.4	1.5	0.9
Assemble trip dogs and adjust high-low spindle speed clutch	4.1	5.5	2.9	2.5
Set each of 6 trip pins 3 times (average)	15.3	20.3	4.7	2.6
Change feed gears	....	3.3	1.7	3.2
Total	60.1	72.1	27.4	23.1
Total, per cent	100	120	45.6	38.4
Improvement, per cent	....	−20	+54.4	+61.6

[a] Totals are in proper ratio each to the other, but data here presented are not for quantitative use.

TABLE 2 MOTION STUDY OF A SINGLE ELEMENTAL SETUP: "CHANGE COLLET CHUCK"

Old model	Time, min	First and second revisions	Time, min	Third revision	Time min
Remove two shield screws	0.53	Loosen clamp screw in collar	0.53	Lift cover	0.03
Remove shield	0.32	Unscrew collar (spanner)	0.43	Unchuck	0.08
Loosen chuck hood (pin and mall)	0.67	Remove collar	0.14	Loosen and remove 3 pads from chuck	0.48
Unscrew hood	0.95	Force out chuck	0.07	Replace and secure 3 pads in chuck	0.66
Hood off and wipe out	0.32	Position spanner (loosen chuck)	0.18		
Remove chuck	0.08	Unscrew chuck and remove	0.50		
Replace new chuck	0.10	Wipe out spindle	0.31		
Oil hood and pilot	0.35	Replace new chuck and assemble	0.53		
Replace hood (by hand)	0.42	Secure chuck (spanner)	0.50		
Secure hood (pin and mall)	0.59	Locate chuck or pin	0.05		
Replace shield	0.31	Assemble collar	0.31		
Assemble two shield screws	0.66	Secure with spanner	0.22		
Secure two screws	0.16	Secure clamp screw	0.34		
		Oil chuck	0.25		
Total time	5.46		4.36		1.25

Table 2 shows the degree of breakdown necessary for such studies. Such a breakdown was made for each element in the series.

Obviously, systematic effort is required. No haphazard informal consideration will produce the desired results. Making such a breakdown may seem unnecessary to the uninitiated, but if one considers the importance of separating indirect, direct, and unnecessary elements from the standpoint of instituting design changes, elaborate analysis is justified.

Critical examination of Table 2, for example, reveals that only two out of thirteen elements on the old model were "direct." In the case of the first and second revisions, only two out of fourteen elements were direct. It is a general rule of methods engineering that *where the ratio of direct to indirect elements in a cycle is not improved, time savings will be small.* In the case of the first and second revisions, compared to the old method, the time saving was only about 20 per cent.

The third revision has two direct elements out of a total of

TABLE 3 A STUDY OF CAUSES FOR SETUP TIME CHANGES

Element of setup	First revision compared to old model: Improved	Worsened	Cause
Change collet chuck	x		Use of draw-in collet instead of pushout type, resulting in fewer changes during setup.
Change feed fingers	x		Elimination of small tools in the removal of tube from machine and its replacement.
Adjust stock feed	x		Concentration of all adjustments in one place, and the elimination of "measure" as an element.
Adjust chuck tension	x		Elimination of hand-cranking the machine through the chucking part of the cycle.
Change spindle speed gear		x	Inclusion of sprocket-range change as well as gear change. Six bolts in sprocket-gear cover for oil tightness.
Adjust two cross slides	Same		No change.
Adjust feed cams		x	Addition of covers. Inaccessibility caused by high barriers around cam drum.
Assemble trip dogs and adjust high-low spindle speed clutch		x	Addition of covers. Inaccessibility caused by high barriers around cam drum.
Set each of 6 trip pins 3 times (average)		x	Addition of covers. Inaccessibility caused by high barriers around cam drum.
Change feed gears		x	No feed change gears in original machine. Range of machine extended.

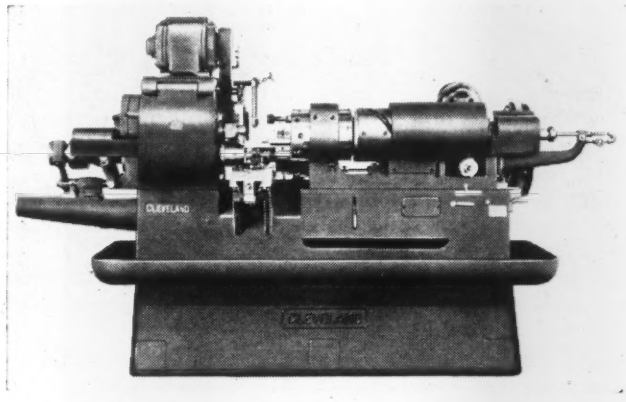

FIG. 4 ORIGINAL SINGLE-SPINDLE AUTOMATIC SCREW MACHINE USED AS BASIS OF COMPARISON IN STUDIES

four. With this favorable change, a time saving of about 77 per cent resulted. This demonstrates the principle, *Efficient machine setups can only be attained where the ratio of direct to indirect elements in the setup procedure approaches or is greater than one to one.*

TABLE 4 STUDY OF CAUSES FOR IMPROVEMENT

Element of setup	Second revision of design compared to first revision: Improved	Cause
Change collet chuck	No	No change in design.
Change feed fingers	No	No change in design.
Adjust stock feed	Yes	Use handwheel and graduated scale.
Adjust chuck tension	Yes	Elimination of loose hand lever.
Change spindle speed gears	Yes	Elimination of nuts holding gears to shaft. Substitution of cover which holds gears in place.
Cross-slide adjustment	Yes	Substitution of a simple clutch selector for actual movement of cams on drum.
Adjust feed cams	Yes	Elimination of need to walk around machine, and substitution of feed dials for actual movement of cams on drum.
Assemble trip dogs, adjust clutch	Yes	No covers over trip-dog drum. Hood, hinged, replaces removable cover.
Set each of 6 trips	Yes	Substitution of graduated dial on trip-pin drum in place of cut-and-try setting. Open drum, no covers to remove, or barriers to work around.
Change feed gears	Yes	Elimination of nuts holding gears to shaft. Substitution of cover which holds gears in place.

TABLE 5 STUDY OF CHANGES MADE IN MACHINE DESIGN AND EFFECT ON SETUP

Element of setup	Second to third revision: Improved	Worsened	Cause
Change collet chuck	x		Substitution of master chuck requiring only pad changes.
Change feed fingers	x		No cover removal. Hinged hood substituted.
Adjust stock feed		x	Special wrench used instead of handwheel.
Adjust chuck tension	x		Better accessibility. More room for hands and tools.
Change spindle speed gear		x	More bolts necessary in cover to insure oil tightness.
Adjust two cross slides	No change		
Adjust feed cams	x		Dials and timing cams, including cross-slides, located closer to each other.
Assemble trip dogs, adjust clutch	x		Location closer to working section of machine.
Set 6 trip pins	x		Location closer to working section of machine.
Change feed gears		x	More bolts necessary in cover to insure oil tightness.

The usual result of the first redesign to extend machine capacity and performance is manifested in Table 3. The set-up problem on the machine became much worse!

Causes for the worsening of setup time are obvious from inspection of Table 3. They may be divided into two classifications, as follows:

1 Widening of the range of the machine, increasing transmission setup complexities, and adjustment difficulties.

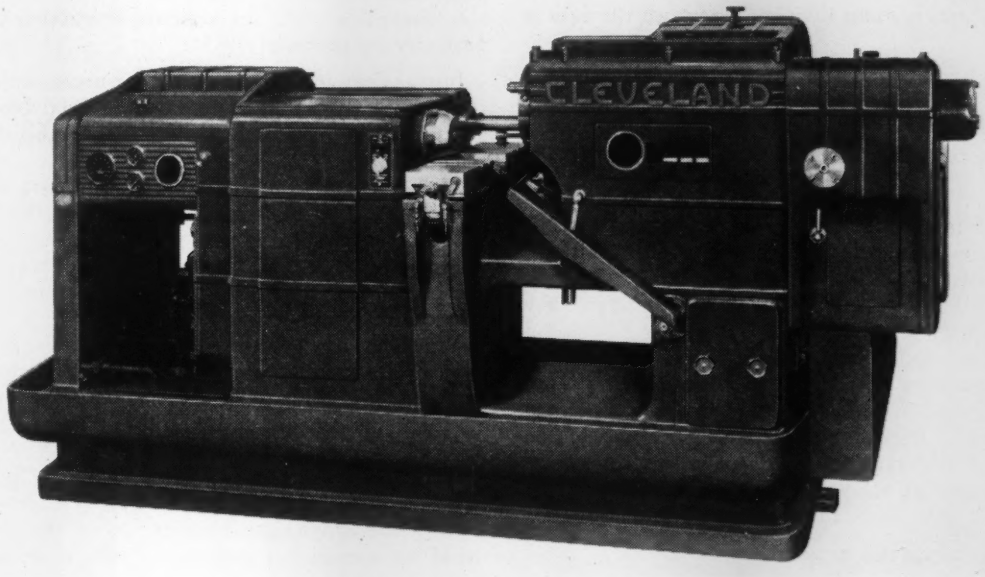

FIG. 5 FIRST REVISION OF AUTOMATIC-SCREW-MACHINE DESIGN, MADE WITH ONLY INFORMAL CHECK OF MOTION-ECONOMY PRINCIPLES

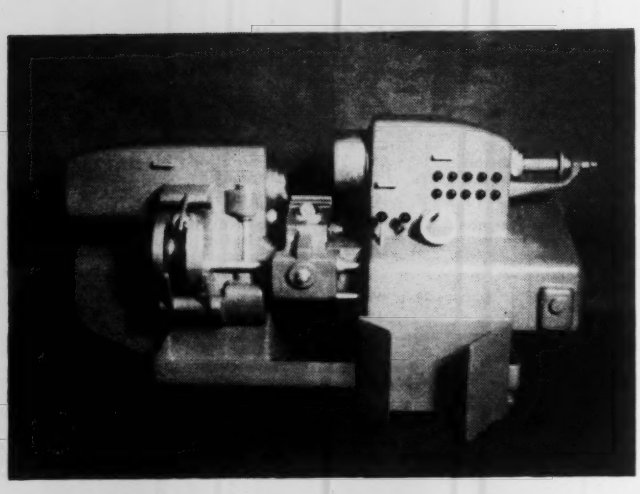

FIG. 6 SINGLE-SPINDLE AUTOMATIC-SCREW-MACHINE DESIGN AFTER SECOND REVISION

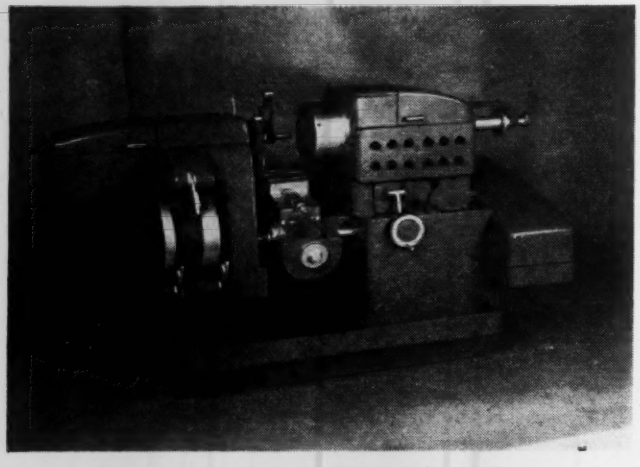

FIG. 7 SINGLE-SPINDLE AUTOMATIC SCREW MACHINE AFTER THIRD DESIGN REVISION

2 Streamlining treatment, placing certain repetitive adjustments under cover and thus increasing the number of indirect elements in the set-up procedure.

Fig. 4 is an illustration of the old model of the machine, while Fig. 5 illustrates the first revision, on which the data in Table 3 are based.

Of the ten major elements in the setup, four only were improved by the first design revision. This change was made without benefit of complete systematic motion study, and the fact that a more complicated setup problem was being designed into the machine was not considered until the machine had been built.

In the second revision, the motion analysis of the drawings was helpful in pointing out design changes which resulted in improvements shown in Table 4.

Fig. 6 shows the second-revision design, compared in Table 4 to the design of Fig. 5.

The final revision was largely a matter of further simplification of motions necessary for setup. In some cases, it was necessary to go backward in so far as setup time was concerned, in order to provide a dependable mechanism. Practical considerations always moderate desirable action. A comparison of the third revision with the second revision is given in Table 5, while Fig. 7 is a view of the third-revision design.

GENERAL RULES FOR GUIDANCE OF DESIGNERS

As a result of experimental procedure, and experience with the design of the automatic screw machine used as the illustration in this paper, rules for design are proposed as follows:

1 Avoid all loose covers. Where covers are necessary, use hinged hoods.

2 All functional machine adjustments should be in the open, unless safety or lubrication demands that they be covered.

3 Adjustments which affect working-tool positions or timing should be made from a point where the effect on the tools can be observed.

4 Graduated dials should be provided for timing and feed adjustments.

5 Graduated dials should be provided for speed adjustments.

6 Where necessary to use bolts and nuts for adjustment, limit the number of sizes. Use only one size, if possible.

7 Provide micrometer dials for the elimination of "loosen, tap, and tighten" adjustments.

8 Design all hoods, doors, or guards, so that they will not be "barriers" to the setup man.

9 Provide fixed locations for loose tools.

10 Use handwheels and cranks instead of wrenches, if possible.

11 Provide fixed measuring gages for the elimination of "measure" elements in setup cycles.

12 Bring machine adjustments to a single station, in so far as possible.

CONCLUSION

Before a machine can reflect well-rounded design, it must show the results of a systematic and thorough correlation of (1) motion study; (2) machine design; (3) tool design; (4) research (experimental); (5) industrial design.

Motion study in preliminary design stages does better, and more systematically what designers have long tried to do in a less scientific way:

1 It locates and evaluates all setup or operator time which the machine requires and separates the elements of such time into the following:

(*a*) Direct, or productive work.
(*b*) Indirect or unproductive, but necessary work.
(*c*) Unnecessary work.

2 Unprofitable and sometimes tiring operations which are required are pointed out.

3 It shows the cause for tiring operations.

4 Possible corrective measures are clarified, so that guesswork in design changes is minimized.

5 It records, for future use, logical solutions to recurrent design errors.

6 Statistical data for accurate prediction of machine productivity are provided.

Just as drawings can provide the necessary information for the stress analyst, they can provide essential data to the motion-study analyst, so that changes in operability can be made scientifically.

With each motion study, systematic data are accumulated and filed, so that in each successive study, the accuracy of prediction increases.

Motion study as a phase of the design of production machines must occupy an important place in the planning and organization of every new design project.

We believe the worth of a machine to the purchaser is measured by its productivity, and it must therefore possess this quality if it is going to be priced so that it will guarantee to the machine builder and user alike a profitable manufacturing return.

The true measure of productivity is the "production experience" which the user of the machine achieves. Only by minimizing the down-time for setup, tool change, and machine handling can higher production experience be attained. In turn, the only systematic method for the improvement in setup, tool change, and handling is through the use of motion study in the early stages of the machine development program.

Use of RUBBER *in* POWER-DRIVE LINES

By JAMES H. BOOTH

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CONSIDERING the use of a rubber coupling in power-drive lines as a method of securing torsional flexibility and changes of angular relationship, the designing engineer finds many advantages. Checking these advantages, we have a coupling that is free from lubrication requirements and is not affected by dust and dirt. The shafting lines may be kept on center, which is a desirable feature. Most mechanical-type couplings require the shafting to be operated off centers, as experience has shown severe brinelling when the mechanical type is run with shafting that is operated on centers. Shafts working in nearly perfect alignment have less tendency to go into vibrational periods, and the power loss is reduced.

A rubber coupling permits wide ranges of torsional flexibility, depending upon the rubber hardness, and also upon the method of using the rubber, as in shear or compression. Rubber in the drive line assists in breaking up torsional-vibration periods by virtue of the natural hysteresis characteristics of the rubber. Power losses are at a minimum, as the power used to turn the joint to a definite angle is stored in the rubber and is transmitted back to the shaft as it returns to its neutral position. In most designs slip splines may be omitted, since rubber in the shaft line permits end deflection along the longitudinal axis of the shaft.

TYPES OF RUBBER COUPLINGS

There are many methods of applying rubber in power-drive lines, but this discussion will be confined to the limitations of a design composed of rubber blocks in a housing, using rubber in compression for the driving torque. However, for reference we should examine Fig. 1, which shows a coupling in which the rubber is used in shear. While many satisfactory applications of rubber in shear have been made, this design has two undesirable features which greatly limit its use. The shear-type design depends entirely upon the rubber bonded to a metallic surface and, as the rubber is very soft when used in shear, this design requires large diameters, which is a distinct handicap for most installations. Shear-type couplings are limited to designs where minimum angularities are required and small amounts of power are to be transmitted.

The coupling which we shall discuss in detail is shown in Fig. 2. This coupling was designed and patented by F. M. Guy and is manufactured in England under the name "Layrub." Before the war, the coupling was also manufactured in Germany, France, and Italy. In the United States, this type of coupling is manufactured for marine, industrial, and accessory use by the Morse Chain Company under the trade name "Moreflex." On all types of vehicles and equipment where power is transmitted to the drive wheels, such as cars, trucks, streetcars, etc., this product is manufactured by the author's company and is known as the "Thompson" coupling. The two English racing cars that were designed for the maximum speed record, namely, the *Railton-Cobb* and the *Thunderbolt*, were equipped with this type coupling in the power-drive line.

Eight installations of this rubber coupling were made in the drive lines of the *Railton-Cobb*. This car made an official record of 368.85 mph, and the official record of the *Thunderbolt* was 357.50 mph. There is no doubt that the rubber couplings on these cars assisted in attaining these high speeds, as any rubber in the drive line has the ability to absorb power which is finally placed back in the drive line. When the driving wheels on any high-speed car leave the ground and, consequently, attain higher revolutions than the normal driving speed, there is a sudden shock-loading throughout the drive when the wheels return to a traction position. With rubber in the drive line, a large amount of the energy of this shock-loading is absorbed by compressing the rubber in the coupling, and, as the

Contributed by the Rubber and Plastics Group and presented at the Annual Meeting, New York, N. Y., Nov. 29–Dec. 3, 1943, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

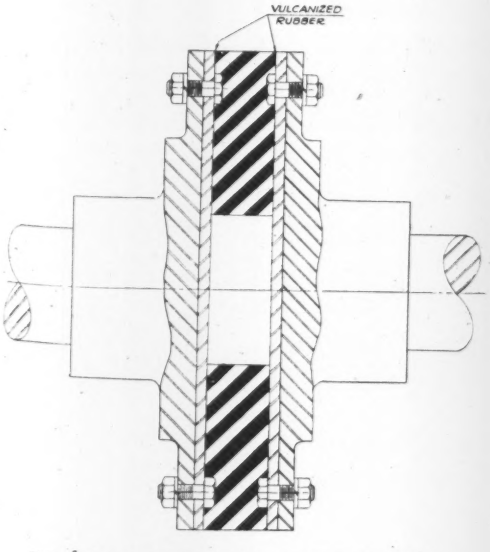

FIG. 1 COUPLING USING RUBBER IN SHEAR

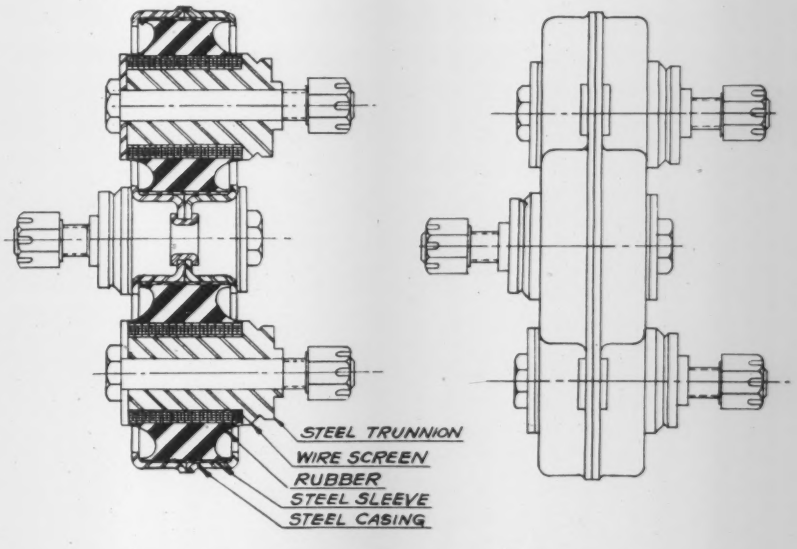

FIG. 2 COUPLING USING RUBBER IN COMPRESSION

rubber is returning to its normal driving position, this energy is transmitted back into the power line.

PHYSICAL CHARACTERISTICS OF RUBBER IN COUPLINGS

Turning to a consideration of the physical characteristics of the rubber block used in this coupling, this block consists of a metal or fabric outer shell and an inner core composed of rolled-up wire screen. Fig. 2 shows a sectional drawing of the block with rubber bonded to the outer metal sleeve and impregnated through the wire-screen core. This wire-screen core was developed after many attempts had been made to create a satisfactory bond between the rubber and a metal core. Most rubber engineers request an adhesion load on a bonded surface of this type not to exceed 100 psi, and tests substantiate this figure, as rubber bonded to a metal core has not proved adequate. A core composed of rolled-up wire screen permits the rubber to flow through the open mesh and, assuming that a rubber is used of 3000 psi tensile strength, and the multiple layers of screen result in a projected area of half screen and half rubber, the bond secured in this manner amounts to approximately 1500 psi, as compared with the 100 psi of the bonded-type core.

After the block has been molded, the outer shell is swaged to place the rubber under compression, as experience has shown that the rubber block has a higher fatigue life in a compressed condition. Compressing the block reduces the load rate of the rubber to move endwise or at right angles to the compression load. This is a distinct advantage on vehicle drive-line installation, as it results in low thrust loads on the drive-line bearings, which will be discussed in more detail later.

The finished shape of the rubber block is highly important and extensive tests have resulted in the contour shown in Fig. 2. While a certain amount of theory is successful in contour design, best results are usually obtained by making minor alterations in the contour and running each possibility to failure on test equipment.

The completed blocks are carried in a housing, which usually consists of two stampings riveted together, as shown in Fig. 2. Since the war many variations have been made in the housing, because of the requirements of military vehicles, especially tanks. Some tank applications require that the flexible coupling be placed between the final driving cog and the drive gears. In some installations, the coupling has been made part of the flywheel assembly, and in others the coupling is placed between the drive gears and the torque converter.

Rubber hardness is highly important to the flexibility of the coupling; the difference in deflection of two hardnesses of a rubber block is shown in Fig. 3. It will be noted that on loads up to 600 lb, the difference in deflection is small, but on the higher loads the difference in deflection is large, which means that a coupling using blocks of the softer rubber will have much greater torsional deflection under shock-loading.

The angular deflection between the various sizes of couplings of one rubber hardness is shown in Fig. 4. In this figure, it will be noted that the deflection angle of the completed coupling is quite sensitive to the diameter of the coupling and block cross-sectional dimensions. From this same chart we observe that at 200 ft-lb torque, the deflection of the 6-in. coupling is approximately twice that of the 7-in. coupling.

In addition to angular deflection, this coupling receives end-thrust load, as illustrated in Fig. 5, which shows a typical installation in a motor vehicle of the Hotchkiss-drive design. In this design the drive from the axle is taken through the leaf springs to the frame and, as the axle moves up and down resulting from the spring travel, the arc described by the drive line *B* is much greater than the arc described by the spring portion *A*. These arcs result in an effective shortening and lengthening of the drive shaft. Where mechanical couplings are used, a slip spline is provided, but in the case of the rubber coupling the effect is obtained by end deflection of the rubber, since it is not usually necessary to use a slip spline where these couplings are installed. The end loads resulting from this type of movement for three sizes of couplings are shown in Fig. 6.

Angular deflection of the coupling results in energy being consumed as the rubber is deflected owing to angle, but this energy is transmitted back to the power line as the rubber returns to its normal position. Tests at the University of Michigan by Prof. Benjamin F. Bailey show (Fig. 7) the efficiency of the coupling to be almost 100 per cent up to angles of 16 deg. Quoting from Professor Bailey's report:

"In fact, some of the results show an apparent gain in the joint, which, of course, is impossible. In other words, the loss in the joint, if any, was less than could be observed with any degree of consistency. Certainly the loss was not greater than one half of one per cent, even at the extreme angles used. In the case of the ordinary joint (mechanical joint) used for comparison, it will be noted that the loss increased quite consistently and became very large with the largest angle. An attempt was made to measure the loss with a slightly larger angle, but the noise and vibrations were so excessive that observers were afraid to continue. In the case of the rubber joint, using the greatest care it was impossible to detect any systematic indication of loss in the joint. The operation was perfectly smooth and noiseless, even at very extreme angles."

RELATION OF SHAFT SIZE AND RUBBER COUPLING

The selection of shaft size and length is highly important in any power-drive installation and, while the rubber coupling will change the natural frequency period of the whole assembly, it is well to select a shaft having a natural vibration

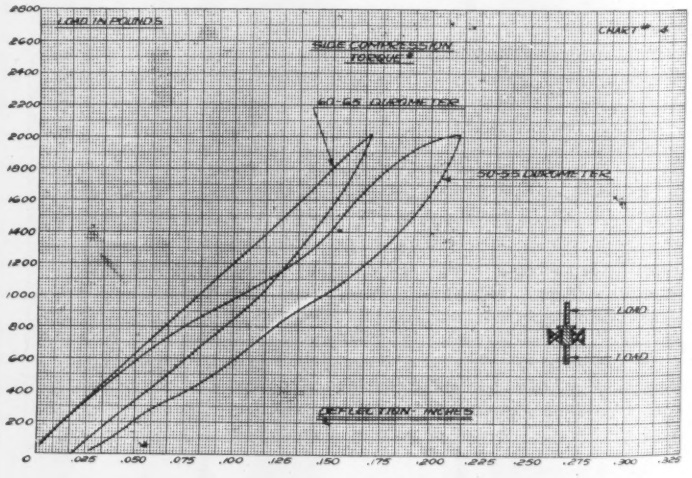

FIG. 3 DEFLECTION VERSUS LOAD FOR DIFFERENT HARDNESS OF RUBBER

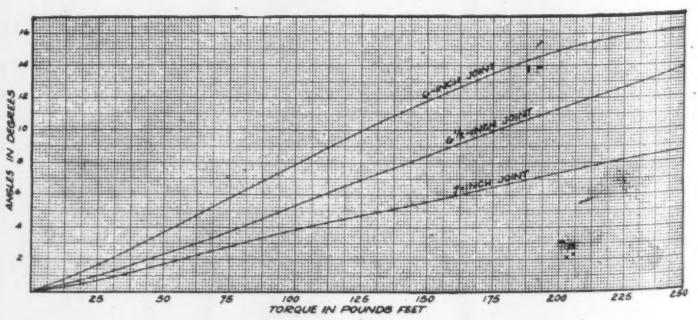

FIG. 4 ANGULAR DEFLECTION OF VARIOUS-SIZE COUPLINGS; SAME HARDNESS

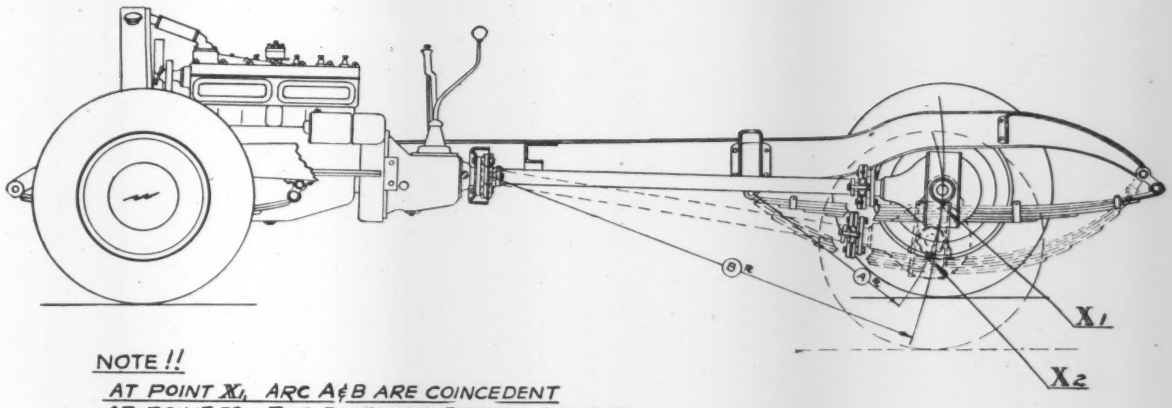
X1
X2
NOTE !!
AT POINT X1, ARC A & B ARE COINCEDENT
AT POINT X2, THE DISTANCE BETWEEN THESE
ARCS REPRESENTS END MOVEMENT THAT IS ABSORBED
IN RUBBER COUPLINGS.

FIG. 5 END THRUST ON COUPLING IN TYPICAL INSTALLATION

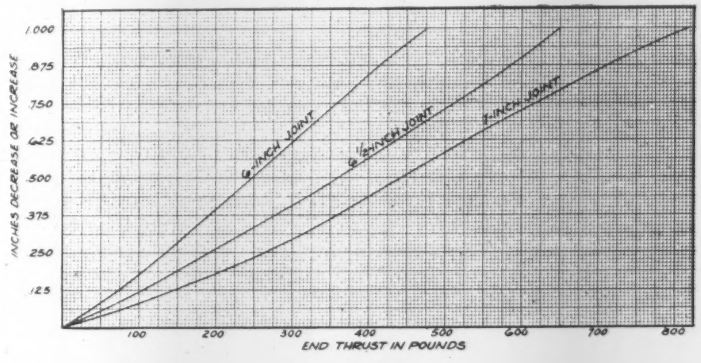

FIG. 6 END THRUST REQUIRED TO INCREASE OR DECREASE LENGTH OF SHAFT FROM NORMAL; NO ANGULARITY IN JOINTS

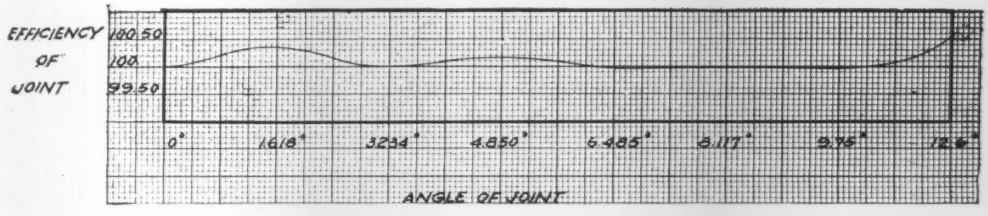

FIG. 7 EFFICIENCY OF COUPLING FOR VARIOUS ANGLES OF DEFLECTION

frequency above the requirements of the installation that is being considered. S. Timoshenko[1] states: "The critical speed of a rotating shaft is that speed at which the number of revolutions per second of the shaft is equal to the frequency of its natural lateral vibrations."

Vibration periods of the whole drive-line assembly often result in brinelling of the transmission and rear-axle gears. In one truck unit that is used for excavation purposes, where the terrain is extremely rough, transmission life was increased approximately ten times by the installation of this type rubber coupling in the drive line.

The formulas used for the selection of the correct rubber couplings for passenger cars are based upon the horsepower rating of the coupling at 50 mph, against the horsepower required to propel the vehicle at 50 mph on a 6 per cent grade. This is a constant rating based upon torque capacity of the coupling. Experience indicates that the occasional load duty may be 300 per cent of constant-torque load. This reserve covers acceleration in gear, hill climbing, and braking through the propeller shaft. The actual horsepower required appears to be the best criterion and is determined by means of the following formulas:

$$HP = HP_L + HP_G + HP_A$$

where

HP = total horsepower
HP_L = horsepower to overcome rolling resistance on level
HP_G = horsepower to climb grade
HP_A = Horsepower to overcome air resistance

$$HP_L = \frac{GVW \times RF \times 88m}{33{,}000}$$

$$HP_G = \frac{GVW \times GF \times 88m}{33{,}000}$$

$$HP_A = \frac{m^3}{3800}\left(\frac{A\,v^3}{240{,}000}\right)$$

where

[1] "Vibration Problems in Engineering," by S. Timoshenko, second edition, D. Van Nostrand Company, Inc., New York, N. Y., 1937.

(Continued on page 397)

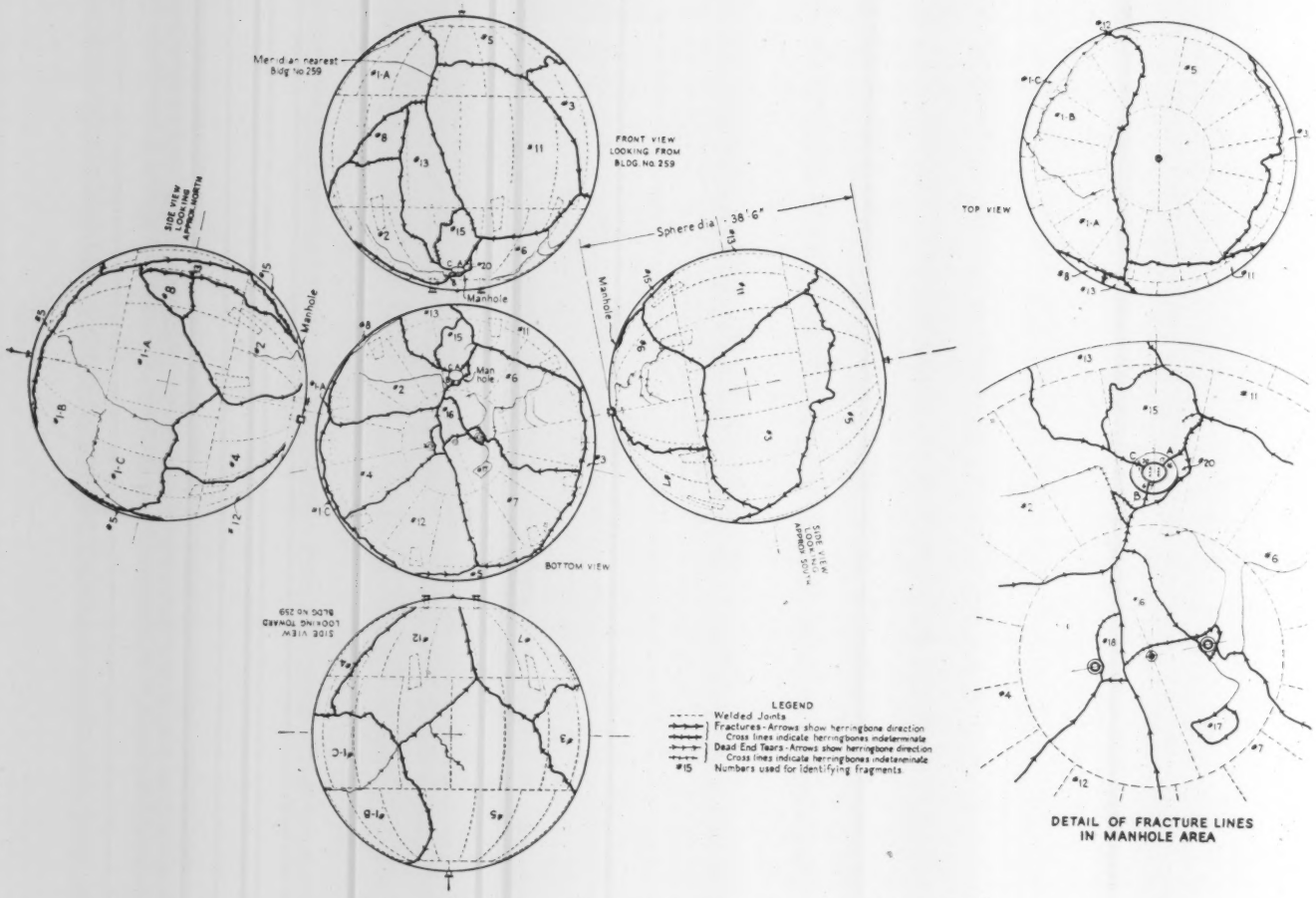
Meridian nearest Bldg No 259
FRONT VIEW LOOKING FROM BLDG. NO. 259
Manhole
Sphere dia - 38' 6"
TOP VIEW
BOTTOM VIEW
LEGEND
Welded Joints
Fractures - Arrows show herringbone direction. Cross lines indicate herringbones indeterminate
Dead End Tears - Arrows show herringbone direction. Cross lines indicate herringbones indeterminate
Numbers used for identifying fragments
DETAIL OF FRACTURE LINES IN MANHOLE AREA

FIG. 1 EXTERNAL VIEWS OF SPHERE SHOWING FRACTURE LINES

FAILURE OF SPHERICAL HYDROGEN STORAGE TANK

By A. L. BROWN[1] and J. B. SMITH

INSPECTION DEPARTMENT, ASSOCIATED FACTORY MUTUAL FIRE INSURANCE COMPANIES, BOSTON, MASS

ON Feb. 16, 1943, at 2:47 p.m. eastern war time, a spherical hydrogen storage tank, 38.5-ft in diameter, located beside the gas generator building, General Electric Co., Schenectady, N. Y., failed structurally with explosive violence. The sphere was made of welded steel plate, and materials, design, and erection were in accordance with the A.S.M.E. Code. The tank was designed for a working pressure of 50 psi and contained hydrogen gas at about 50 psi gage pressure. It was protected against normal excess pressure by two 2-in. relief valves. One of the valves, not seriously damaged by the accident, was tested with air and found to open properly at from 53 to 58 psi gage.

Immediately preceding the accident there was a 36-hour period of subzero temperature, following which the thermometer rose about 27 F in seven hours and was about 10 F when failure occurred. At this time the sun was shining on a point about diametrically opposite the manhole.

The generally excellent quality of the welding is demonstrated by the fact that only a few feet of fracture followed the many feet of welded seams. It is significant also that the fractures did not involve, except in a minor way, the support-leg attachments where there are concentrated stresses due to the loads from the dead weight of the sphere.

Occurrence of Fractures. The sphere burst into about twenty fragments (Fig. 1). Each piece was surveyed, and using the welds as reference lines, all fractures were plotted to scale on a model sphere 15 in. in diameter. An inspection was also made of the characteristic "herringbone" markings (Fig. 2), indicative of the direction of tearing, on both edges of the total of 650 ft of fracture; and arrows showing the actual herringbone

[1] Member, A.S.M.E.

From a report by the Inspection Department, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.

A subcommittee, appointed by the A.S.M.E. Boiler Code Committee, is reviewing the accident described in this report as well as other related experience. If the causes of the accident can be avoided by changes in the rules of the A.S.M.E. Unfired Pressure Vessel Code, this committee will offer suggestions to the Boiler Code Committee. For this reason, recommendations contained in the Associated Factory Mutual Fire Insurance Companies' report, which would directly involve changes in the Code requirements, have been omitted from this article.—Editor.

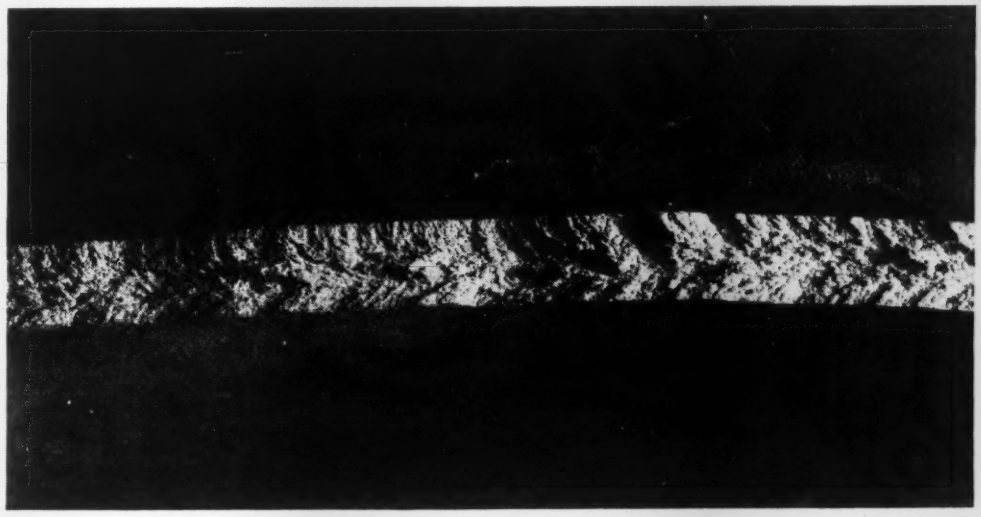

FIG. 2 TYPICAL "HERRINGBONES" ON FRACTURE EDGES
(Arrows formed point toward origin of tear.)

directions were drawn on the fracture lines. This synthesis indicated that failure began at the 20-in-diam manhole neck. The arrows shown on the fracture lines (Fig. 1), point in the direction of the "herringbones" which themselves point toward the tear origin. From the manhole the tears radiated over the entire surface, almost instantaneously, releasing the fragments, which were blown into their final resting places by expansion of the compressed hydrogen. The intensity of failure was greatest near the manhole and in the bottom cap.

Reasoning from convex and concave bends found in the manhole cover, the failure originated at point *C* (Figs, 1, 3, 4, and 5), in an incipient crack in the sheared inside edge of the neck where plate shears had left a torn surface. From *C* a fracture ran to the left (facing the manhole, Fig. 1). Also along this line a bulge from internal pressure started and produced second and third fractures at similar incipient cracks in the neck at *A* and *B*. The initial movement produced the slight but noticeable convex cover bend (Fig. 5). Immediately following, the fractures freed fragments 15 and 2, and the remote ends, moving radially outward, produced the marked concave bend in the cover and the failure of the bolts by combined tension and shear.

In the meantime, the fractures beginning at *B* and *A* had run, respectively, down to the left of fragment No. 12, and up to the left of fragment No. 11 across the pole caps to the junction at the top of No. 12. This formed the first complete circumferential fracture dividing the sphere in two hemispheres. The final resting places of the fragments supports this reconstruction of the progress of the failure which proceeded so rapidly, because of the self-producing-shock character of the breaks, that almost complete fragmentation occurred before anything more than the initial acceleration of individual pieces was under way.

The fragment locations also indicate that fractures nearest the manhole separated first in a manner which caused the sections to hinge more or less about their "trailing" edges. This accounts for their landing slightly off the extended radii joining their centers with the center of the sphere. The minimum hinging would be expected where the first fractures, having the highest velocities, developed; this is found to be true of the fragments nearest the manhole and also of Nos. 11 and 12, which must have been among the first to separate since they were thrown furthest by internal pressure.

All eight anchor bolts attaching the V posts to the footings were sheared outward. Three of the four welded support base plates were torn from the V posts. Three of the V posts remained attached to sphere fragments.

The Cause. On the basis of available information, this sphere is the only one of about five hundred already installed to fail structurally while in service. Although, at first, appearances indicated that an internal-combustion explosion had occurred, this theory was not supported by the evidence.

It was concluded that the structural failure resulted from the accidental coincidence of a number of factors, each unfavorable to the stability of the sphere, which, if considered singly, would probably not have seemed serious.

The unfavorable factors included:

(1) A stress level, from the normal internal hydrogen pressure, that was higher at the manhole neck than elsewhere in the sphere owing to the stress-raising effect of the 20-in. opening, despite its reinforcement.

(2) Residual stresses of yield-point values in the same location due to the shrinkage of the large amount of weld metal deposited in the joint between the manhole neck and the reinforced sphere plate. These stresses are believed to be triaxial, as shown in detail in Fig. 3. They would seriously restrict plastic flow necessary for self-relief of the stresses so that failure could occur after relatively little additional stress.

The inner edge of the manhole neck was deformed radially outward up to $^1/_8$ in. by shrinkage stresses from welding (Fig. 4) which showed that the metal at this location had been stressed above its yield point and retained yield-point stresses except where partly relieved by local cracking.

Attesting to the severity of these stresses and the restricted plastic flow was the apparent presence before the accident of one large radial crack, and possibly others, in the manhole neck adjacent to the afore-mentioned weld. These cracks are discussed later in this article.

(3) The greatly increased brittleness, under the low-temperature conditions, of the particular grade of welded plate used, when notched as by cracks and when exposed to a relatively slight shock. This characteristic was established by Charpy impact tests on samples cut from the failed sphere and is a well-known property of the semikilled steel involved. In addition to the brittleness of the plate were the biaxial stresses from the internal pressure which are equal in both directions throughout a sphere. These factors, combined with the large amount of energy available from the compressed gas as compared with water, resulted in the continued progress of initial fracture into many tears which separated the sphere plate into a number of pieces that were thrown forcibly outward.

(4) The probable occurrence of some type of shock imparted to any part of the sphere. This may have been the formation of another crack, similar to the one at *F* (Figs. 3 and 6), as a

result of increasing hydrogen pressure caused by the rapid rise of outdoor temperature and the sun's rays; or possible increases in plate stresses, particularly in the area around the manhole, due to uneven heating by the sun's rays of portions of the sphere, or, in view of the unusually cold weather, to frost shock transmitted through pipe connections or support legs from the frozen ground.

DESCRIPTION OF SPHERE

The sphere plates of steel 0.66 in. thick were arranged in five zones corresponding, from top to bottom, to the Arctic, North Temperate, Torrid, South Temperate, and Antarctic zones, into which the earth's surface has been arbitrarily divided. The Arctic and Antarctic zones contained two plates each; the other three zones, 16 plates each. The vessel was designed in accordance with Par. U-69 of the A.S.M.E. Code for Unfired Pressure Vessels for a maximum working pressure of 50 psi based upon an allowable unit working stress of 11,000 psi and a weld-joint efficiency of 80 per cent.

The plates were shop-formed cold and were erected in the field by the builder of this spherical container during September and October of 1942. The joints were arc-welded. Covered electrodes were used in welding. In line with Par. U-69 of the A.S.M.E. Code, neither the completed vessel nor any part of it was stress-relieved after welding.

The sphere stood on four concrete footings which were carried 5.5 ft below grade. From each footing, two steel-angle support legs diverged and were welded to support pads symmetrically spaced around the horizontal seam, just below the Torrid zone. At the point of attachment the supports were tangential to the sphere.

The sphere was tested with air pressure at 62.5 psi gage for about one hour on Oct. 10, 1942. After the test the pressure was dropped to 50 psi and no leaks were found when the welds were covered with soap solution. Several days prior to October 10 the vessel had been hammer-tested by the erector's workmen while it was filled with air at atmospheric pressure. It was placed in service about the middle of December, 1942.

IMPROBABILITY OF INTERNAL EXPLOSION

Immediately following the accident, a careful study was made to determine if an internal-combustion explosion of hydrogen-air or hydrogen-oxygen mixture had occurred. This included a study of: The sphere history following installation; the detailed method of hydrogen generation and purity tests; low-, intermediate-, and high-pressure pumping and storage systems; operating practice and safety precautions at the gas plant; and a thorough examination of evidence and test of equipment remaining after the accident.

The simultaneous occurrence of a source of ignition and a mixture of air or oxygen with the hydrogen, within the limits of inflammability, would have been required to have an internal-combustion explosion.

The report on which this article is based covers the details of the hydrogen system, the possibilities of ignition of an explosive mixture, whether or not such a mixture could have been present, and what evidence there was that the failure was caused by internal-explosion pressure. The theory of internal explosion is not supported by the evidence.

Calculations indicate that there was sufficient energy from the expansion of the compressed hydrogen alone, if wholly applied to raising the 65-ton sphere, to lift it about 1800 ft; this would provide many times the energy needed to throw all the fragments to their final resting places.

THE MANHOLE

Description. The manhole, Fig. 7, where the failure is believed to have originated, was designed and welded in accordance with the Code requirements and common practice. It consisted of four parts. The bolting flange and neck constituted one subassembly, and the reinforcing collar and sphere plate comprised the other. Each was welded at the builder's shop and shipped to Schenectady. On the field site the neck and flange assembly was joined with a very heavy weld to the plate and collar assembly while both were lying on the ground.

The neck consisted of a strip $^{3}/_{4}$ in. thick, sheared 9 in. wide, and cut to a length of about $5^{1}/_{2}$ ft. This strip was rolled into a ring 20 in. inside diameter and joined in the shop by a vertical butt-welded joint. The bolting flange was then welded in place and machined to give a finished surface for the cover gasket.

Residual Shrinkage Stresses From Welding. As would be expected, the field weld, for which many passes were necessary in order to deposit the large amount of weld metal, produced severe thermal stresses. These stresses resulted in plastic deformation and potential crack formation in the neck (Fig. 4). The inside circular edge of the neck projected from $^{1}/_{8}$ to $^{5}/_{8}$ in. above the weld into the sphere. In some places this edge was bent outward $^{1}/_{8}$ in. so that the diameter at the inside edge was approximately $^{1}/_{4}$ in. greater than the normal-diameter neck (Fig. 4).

The metal in the neck next to the weld was probably under triaxial stresses. This stress condition would greatly restrain the flow of the metal under yield-point stresses upon which ductility depends. The three different stresses would be (see Fig. 3): (1) The normal horizontal hoop tension; (2) the horizontal radial tension in the neck from shrinkage of the surrounding sphere plate away from the neck; and (3) vertical surface tension parallel to the neck axis caused by shrinkage of the large weld on the outside. The directions of these stresses are indicated in Fig. 3. The reduced ductility under triaxial stresses probably accounts for the crack mentioned (*F* in Fig. 3). When pressed open in a testing machine to expose the inside surfaces, the crack was found to be completely covered with a dark-brown oxide which indicated that it was old and probably had been present prior to the failure of the sphere. However, the manhole fragments were exposed to the weather for about three weeks prior to careful examination. The crack could have occurred at the time of cooling following the weld or, even more likely, under the combined residual cooling stresses and the added stresses produced by the test pressure. It seems likely that the crack did not proceed beyond the multiaxial highly stressed zone at the time, because it occurred while the metal was at normal temperature and not under the cold brittle condition.

Two other unopened cracks *D* and *E* were found and were forced open for inspection. These were only partly oxidized and were light reddish in color, which showed that they were new and had probably been caused by the accident.

Sheared Edge of Manhole Neck. Three main vertical fractures (designated *A*, *B*, and *C*, Fig. 3) were found in radial planes in the neck, as well as two new (*D* and *E*) and one old crack (*F*), already mentioned, which did not become fractures. The vertical fractures branched into horizontal fractures between the bolting flange and reinforcing ring, so that two pieces (*n* and *r*) of the bolting flange separated from the neck. The herringbones on all the vertical fractures and cracks indicated that they originated at the inside edge of the neck.

This inner edge of the neck (Fig. 4), left in the "as-sheared" condition, had a $^{1}/_{16}$-in. step with a rough torn corner. When this edge was buffed and treated with Magnaflux, many minute incipient cracks from $^{1}/_{16}$ in. to $^{1}/_{2}$ in. in length and from $^{1}/_{64}$ to $^{1}/_{32}$ in. deep were found. There was about one such crack in every inch of edge perimeter. While obviously none of these incipient cracks, evident after the accident, was actually involved in the failure, others like them probably provided starting points for the three fractures and the three cracks mentioned. It is well known that such incipient cracks will act as "stress raisers" and provide points of origin favorable to the formation of the larger cracks and fractures.

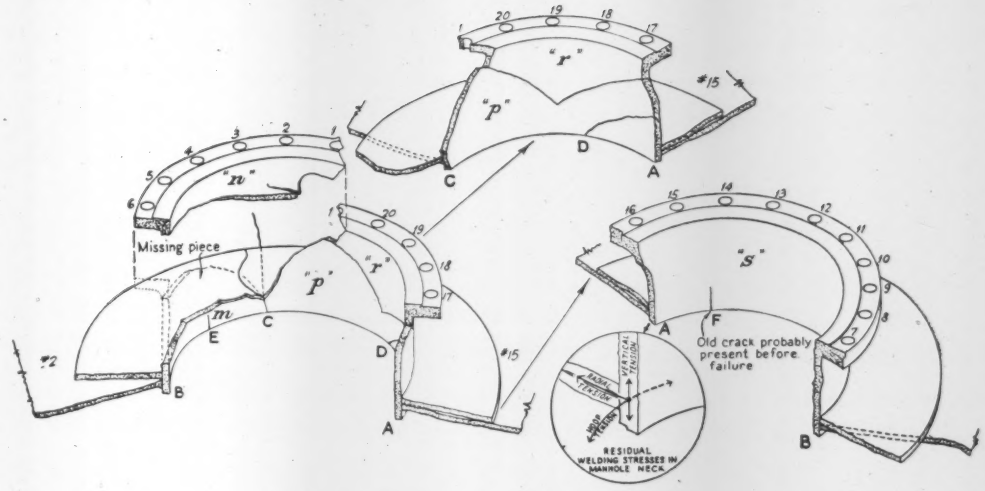

FIG. 3 LOCATION OF MANHOLE FRACTURES

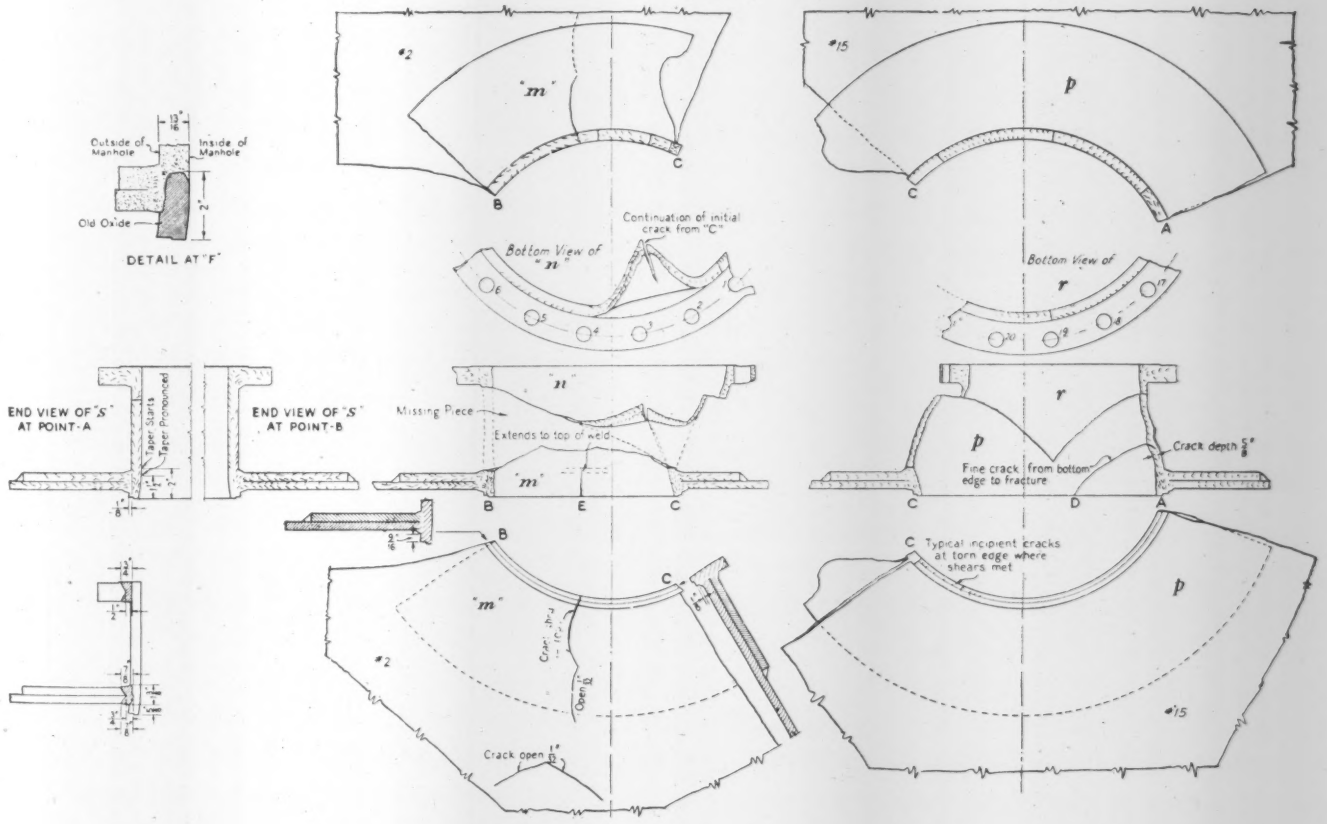
"m"
p
Outside of Manhole
Inside of Manhole
Old Oxide
DETAIL AT "F"
Continuation of initial crack from "C"
Bottom View of "n"
Bottom View of r
END VIEW OF "S" AT POINT-A
END VIEW OF "S" AT POINT-B
Missing Piece
Extends to top of weld
Crack depth 5/8"
Fine crack from bottom edge to fracture
Typical incipient cracks at torn edge where shears met
Crack open 1/8"

FIG. 4 DETAILS OF MANHOLE FRACTURES

Stresses From Internal Gas Pressure. The 20-in. manhole was more than twice the diameter of the next largest opening in the continuous skin of the sphere. Although the opening was designed in accordance with the A.S.M.E. Code, and was reinforced by an annular ring, 7 in. wide and 5/8 in. thick, and a portion of the neck itself, stress studies in other vessels with similar reinforced openings in which actual strains have been measured by means of gage points show that the stress in the plate adjacent to the manhole, resulting from internal gas pressure, could have been expected to be appreciably higher than at any other point in the sphere.

Cumulative Effect of Stresses and Sheared Edge. It is therefore apparent that excessive stresses from thermal contraction after welding were present as evidenced by neck deformation. These stresses, added to the stress from the internal gas pressure, and atmospheric temperature conditions in the presence of the rough sheared edge with its many incipient cracks adjacent to the weld combined to favor the formation of large cracks which would seriously affect the safety of the structure, especially when subjected to a shock. It is therefore likely that the three main vertical fractures in the manhole had their origin at the incipient cracks in the unfinished edge, and there is a strong possibility that one of these incipient cracks had, at the time of accident, developed into a crack comparable in extent to the one found with the dark-brown oxide coating and that this was the trigger setting off the rapid progressive failure under the brittle plate conditions.

CONCLUSIONS

The character of this failure was due chiefly to the brittleness, under the conditions existing at the time, of the steel plates from which the sphere was constructed. Such brittle-

ness, as shown by notched impact tests of the steel at corresponding temperatures, combined with stresses of a character (multiaxial) which restricts ductility and favors a brittle type of fracture, brought about a characteristic fragmentation or a rupture into a considerable number of pieces with the fractures showing little evidence of the reduction in area or shear which would be present with a simple tension failure. Much more extensive fracturing of this type can occur from the expenditure of a given amount of energy than if the breaks were of the more frequently experienced unidirectional tension type occurring in plate of normal characteristics.

Failure by extensive fragmentation may give an impression

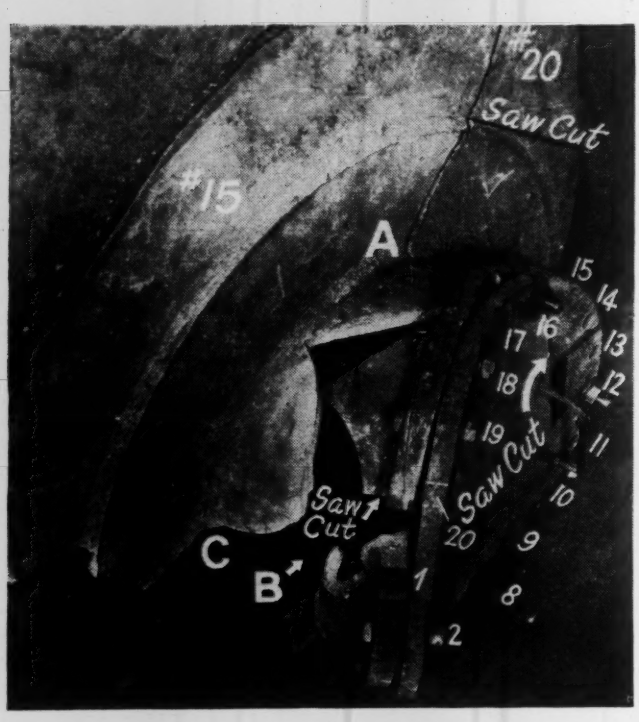

FIG. 5 DOUBLE BEND IN MANHOLE COVER
(Reassembly of fragments except No. 2.)

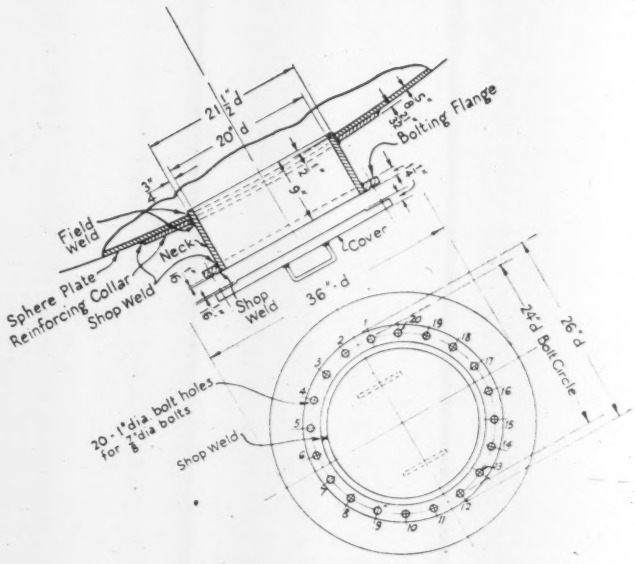

FIG. 7 MANHOLE DESIGN

of the existence of energy unusual in character or amount, but such is not necessarily the case. With the great amount of total energy stored in compressed gas and with its potentially rapid rate of release, complete rupturing of some type may result. The external damage is a consequence of the liberation of great energy rather than of the type of fracture of the container.

Neither a low value of notched impact resistance nor the existence of multiaxial stresses reduces the actual ultimate tensile strength of the steel. However, the former leads to the occurrence or spread of fractures under exposure to shock while under stress, whereas the same stress and shock conditions would not produce such extensive fracturing in the case of a more ductile steel. The latter condition, by diminishing the ductile flow of metal, has the effect of raising the yield point to values approaching the ultimate strength, thereby interfering with a reduction of high local stresses by stretching in the vicinity. If stresses up to the yield point have occurred, they will remain at a value not safely below the ultimate

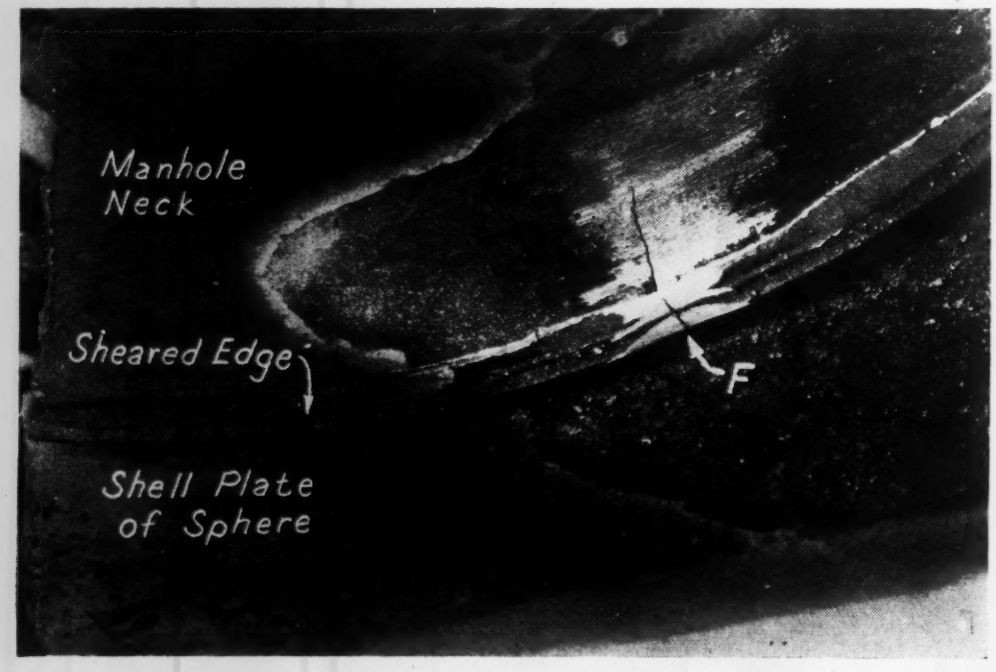

FIG. 6 OLD CRACK AT F, FIG. 3, IN INSIDE EDGE OF MANHOLE NECK AFTER BUFFING AND MAGNAFLUX

strength. A relatively small additional stress or shock can then produce a failure.

This accident demonstrates that the use of steel having a low notched impact value at operating temperature favors the development and progress of the failure. It therefore seems a sound move in a practical direction, when constructing vessels of this type, to call for steel having a good notched impact value at the minimum temperature to be anticipated at the location of the vessel.

It is important that, in the design of structures which have considerable energy available for self-destruction and serious external damage, the metal be of good ductility, and also that indeterminate high local stresses produced by fabrication or by poor distribution of working stresses be eliminated, or at least minimized, by all practical measures.

In a non-stress-relieved pressure container, residual stresses of uncertain magnitude can remain after welding, especially at points of complicated stress arrangement. This possibility exists even with the best quality of welding, carefully developed welding procedure, and the use of high-grade, ductile, base metal.

Even though experience has shown that only a very few such structures have failed, the extreme danger to life and property emphasizes the importance of avoiding high residual stresses by methods of proved effectiveness.

Owing to the serious consequences of failure of a gas container under pressure, as demonstrated in this case, a maximum air test pressure of only one and one quarter times the working pressure was applied to this sphere following its completion.

Its value in disclosing defects which are serious structurally or in contributing materially to stress-relief may well be questioned in view of the proportionally larger variables introduced by working conditions. Obviously its adequacy is not comparable with the generally advised and accepted hydraulic test at double the working pressure. Despite the increased cost over vessels not tested in this way there is no apparent sound reason for accepting an uncertain low factor of strength in this hazardous type of equipment.

Manholes should be designed so that weld metal will be deposited where complex or multiaxial stresses will be avoided as far as possible. Reinforcement around manholes or other large openings should be designed and fabricated in conjunction with the manhole to give a unit which will redistribute safely the stresses which would otherwise be carried by the shell of the vessel.

All welds at manholes, nozzle connections, and at the point of attachment of supports should be made in the builder's shop. Following this, the assembly consisting of the detail and the plate to which it is attached should be stress-relieved by drawing in a furnace. Finally, the subassemblies should be treated with magnetic substance and magnetized (Magnafluxed) in order to detect cracks.

The inside edge of manhole necks and other nozzle connections, or similar parts, should be finished smooth so as to remove all surface cracks. Absence of cracks should then be checked by Magnaflux treatment.

Piping connected to a sphere should be designed with sufficient flexibility to prevent transmission of shock or stress to the shell.

In the case of tanks already erected and having manholes of a design similar to that involved in this accident, the minimum additional attention which should be given to checking potential weakness is to Magnaflux the entire manhole region at the earliest time convenient for releasing pressure, and, if necessary for safety, purging the vessel with inert gas or air.

If any cracks are disclosed, the plate containing the manhole should be cut out and carefully replaced by a manhole and plate subassembly as suggested in the preceding paragraphs. However, if the cracks are small they might be removed by grinding without impairing the strength of the structure.

Use of Rubber in Power Drive Lines

(Continued from page 391)

GVW = gross vehicle weight
RF = rolling resistance factor
= 0.015 for concrete roads

$$GF = \frac{\text{per cent grade}}{100}$$

m = speed in miles per hour
A = frontal area of car in sq ft = 20 (estimated average)

To propel the vehicle at 50 mph

$$HP_L + HP_G = \frac{GVW \times 88 \times 50\,(0.015 + 0.060)}{33{,}000} = \frac{GVW}{100}$$

$$HP_A = \frac{50^3}{3800} = 33$$

$$HP = \frac{GVW}{100} + 33$$

Having determined the required horsepower at 50 mph, we can calculate the required coupling by the formula

$$HP = \frac{320TR}{D}$$

where

T = torque capacity of coupling
R = rear-axle gear ratio
D = nominal tire diameter, in.

Torque capacity of coupling based on 400 psi is found from the formula

$$T = CF$$

where

T = torque in pounds feet
C = capacity of trunnion block in pounds per square inch; constant duty = 400
F = load factor of coupling and is found from

$$F = \frac{rld}{6}$$

where

r = radius of trunnion arm, in.
l = length of trunnion-block core
d = outside diameter of trunnion-block core

FUTURE POSSIBILITIES FOR RUBBER COUPLINGS

Because of the tendency of passenger-car designers to add the body stiffness to the frame stiffness, there is a promising future to the use of rubber in the power-drive lines of postwar vehicles. For several years prior to the war the passenger-car manufacturers realized the advantages of stiffness in body and frame combinations to build a lightweight car for high performance. The resulting noise level of such a combination was extremely high, due not only to road noise, but also to gear and wheel noise transmitted through the drive mechanism. Rubber in the drive line reduces the noise level and should receive wide use in the postwar vehicle.

The Unwritten LAWS *of* ENGINEERING

Part 2—Relating Chiefly to Engineering Executives

By W. J. KING

SUPERCHARGER ENGINEERING DIVISION, GENERAL ELECTRIC COMPANY, WEST LYNN, MASS. MEMBER A.S.M.E.

THE following is a partial list of basic commandments, readily subscribed to by all executives but practiced only by the really good ones:

INDIVIDUAL BEHAVIOR AND TECHNIQUE

Every Executive must know what's going on in his bailiwick. This is repeated here for emphasis, and because it belongs at the head of the list for this section. Just remember that it works both ways, as regards what you owe your associates and subordinates as well as yourself.

Obviously this applies primarily to major or significant developments and does not mean that you should attempt to keep up with all the minor details of functions assigned to subordinates. It becomes a vice when carried to the extent of impeding operations. Nevertheless, the basic fact remains that the more information an executive has, the more effectively he can manage his business.

Do not try to do it all yourself. This is another one of those elementary propositions that everyone will endorse and yet violations are quite common. It's *bad* business; bad for you, bad for the job, and bad for your men. You *must* delegate responsibility even if you *could* cover all of the ground yourself. It isn't wise to have so much depend upon one man and it's very unfair to your men. It is often said that every executive should have his business so organized that he could take a month's vacation at any time and have everything go alone smoothly. The most common excuse for hogging the whole job is that subordinates are too young or inexperienced. It's part of your job to develop your men, which includes developing initiative, resourcefulness, and judgment. The best way to do this is to load them up with all the responsibility they can carry without danger of serious embarrassment to the department. Any self-respecting engineer resents being babied, to the extent where he cannot act on the most trivial detail without express approval of the department head.

On the other hand, it must be granted that details are not always trivial and it may sometimes require a meeting of the management committee to change the length of a screw in a critical piece of mechanism in high production. It's simply a matter of making sure that all items are handled by men of appropriate competence and experience.[1]

Put first things first, in applying yourself to your job. Since there usually isn't time for everything, it is essential to form the habit of concentrating on the important things first. The important things are the things for which you are held directly responsible and accountable, and if you aren't sure what these are you'd better find out mighty quick and fix them clearly in mind. Assign these responsibilities top priority in budgeting your time; then delegate as many as possible of the items which will not fit into your schedule. It is a good general rule never to undertake any minor project or chore that you can get someone else or some other department to do for you, so long as it is not an essential part of your job. For example, if your job is building motors it's a mistake to spend time designing special vibration or sound meters for testing them if you can get the laboratory to do it for you.

In handling special problems of this sort, it is usually good diplomacy to let some local office do the job, if they can, before importing experts from another plant or company.

The practice of drawing upon all available resources for assistance can frequently be applied to advantage in respect to your major products, as well as in minor details. This is especially true in a large organization where the services of experts, consulting engineers, laboratories, and other departments are available either at no cost or for much less than it would cost you to get the answer independently. In fact, there may well be cases in which it would be wise for you to limit yourself, personally or as a business manager, to performing only those functions to which you can bring some special talent, skill, or contribution, or in which you enjoy some natural advantage. Some companies, for example, have achieved outstanding success by virtue of their special genius for merchandising the products of others, or by concentrating on the manufacture of a standard competitive article so as to capture the market by lowering the price. Likewise the aircraft companies generally exploit their special aeronautical skill, leaving development of engines, superchargers, propellers, and other components to specialists in these fields. Few of us are versatile enough to excel in more than one or two talents.

Cultivate the habit of "boiling matters down" to their simplest terms. The faculty for reducing apparently complicated situations to their basic, essential elements is a form of wisdom that must usually be derived from experience, but there are marked differences between otherwise comparable individuals in this respect. Some people seem eternally disposed to "muddy the water;" or they "can never see the woods for the trees," etc. Perhaps a man cannot correct such an innate tendency simply by taking thought, but it appears to be largely a matter of habit, a habit of withdrawing mentally to a suitable vantage point so as to survey a mass of facts in their proper perspective, or a habit of becoming immersed and lost in a sea of detail. Make it a practice to integrate, condense, summarize, and simplify your facts rather than to expand, ramify, complicate, and disintegrate them.

Many meetings, for example, get nowhere after protracted wrangling until somebody finally says, "Well, gentlemen, it all boils down simply to this, . . .", or "Can't we agree, however, that the basic point at issue is just this, ...", or, "After all, the essential fact remains that . . . ."

NOTE: Part 1 of this paper appeared on pages 323–326 of the May, 1944, issue of MECHANICAL ENGINEERING.

[1] "Administrative Organization for a Small Manufacturing Firm," by Willis Rabbe, MECHANICAL ENGINEERING, vol. 63, 1941, pp. 517–520.

This sort of mental discipline, which instinctively impels a man to go down to the core to get at the crux of the matter, is one of the most valuable qualities of a good executive.[2]

Do not get excited in engineering emergencies—keep your feet on the ground. This is certainly trite enough, and yet an engineering group will sometimes be thrown into a state of agitation bordering on panic by some minor crisis. This refers especially to bad news from the factory or the field regarding some serious and embarrassing difficulty, such as an epidemic of equipment failures. Most crises aren't half as bad as they appear at first, so make it a point to minimize rather than magnify a bad situation. Do not ignore signs of trouble and get caught napping, but learn to distinguish between isolated cases and real epidemics. The important thing is to get the facts first, as promptly and as directly as possible. Then act as soon as you have enough evidence from responsible sources to enable you to reach a sound decision.

Engineering meetings should not be too large or too small. Many executives carry their aversion for large meetings to the point of a phobia. This is reflected in the common saying that nothing worth while is ever accomplished in a large meeting. It is true enough that large meetings frequently dissipate the subject over a number of conflicting or irrelevant points of view, in a generally superficial manner. But this is almost entirely a matter of the competence of the chairman. A considerable amount of skill is required to manage a sizable meeting so as to keep it on the proper subject, avoiding long-winded digressions or reiterations of the arguments. It should be the function of the chairman, or the presiding senior executive, to bring out the pertinent facts bearing upon the matter, in their logical order, and then to secure agreement upon the various issues by (*a*) asking for general assent to concrete proposals, or (*b*) taking a vote, or (*c*) making arbitrary decisions. Engineering meetings may degenerate into protracted wrangles for lack of competent direction. The danger in this respect seems to be about in proportion to the size of the meeting.

Small meetings, three or four persons, can usually hammer out a program or dispose of knotty problems much more effectively. The chief drawback lies in the possibility that all interested parties may not be represented, and considerable loss or mischief may result from failure to take account of significant facts or points of view. Apart from the actual loss involved, strong resentment or discouragement may be engendered in the neglected parties. (The Revolutionary War was brought about largely as a result of the fact that the Colonies were not represented in the British Parliament.)

There will doubtless be cases in which it is neither feasible nor desirable to have all interested parties represented in engineering discussions, particularly if the participants are well informed. But in general it is fitting, proper, and helpful to have the man present whose particular territory is under discussion.

An excellent expedient for avoiding the objections to either extreme in this respect is to keep the meeting small, calling in each keyman when his particular responsibility is being discussed.

In any kind of a meeting the important thing is to face the issues and dispose of them. All too often there is a tendency to dodge the issues, postponing action until a later date, or "letting the matter work itself out naturally." Matters will always work out "naturally" if the executive function of control is neglected but this represents a low order of "management." Count any meeting a failure which does not end up with a definite understanding as to what's going to be done; who's going to do it, and when. This should be confirmed in writing (minutes).

[2] See also: "Psychology for Executives," by Elliott Dunlap Smith, Harper & Bros., New York, N. Y., 1935.

Cultivate the habit of making brisk, clean-cut decisions. This is, of course, the most difficult and important part of an executive's job. Some executives have a terrific struggle deciding even minor issues, mainly because they never get over being afraid of making mistakes. Normally, facility comes with practice, but it can be hastened by observing a few simple principles.

1 Decisions will be easier and more frequently correct if you have the essential facts at hand. It will therefore pay you to keep well informed, or else to bring out the relevant facts before attempting a decision. However, it is sometimes said that anybody can make decisions when all of the facts are at hand, whereas an executive will make the same decisions without waiting for the facts.[3] To maintain a proper balance in this respect, when in doubt ask yourself the question: "Am I likely to lose more by giving a snap judgment or by waiting for more information?"

2 The application of judgment can be facilitated by formulating it into principles, policies, and precepts in advance. The present paper is an attempt to formulate experience for this purpose. Make up your own code, if you will, but at least have some sort of code, for much the same reason that you memorize the axioms of Euclid or Newton's laws of motion.

3 You do not have to be right every time. It is said that a good executive needs to be right only 51 per cent of the time (although a little better margin would obviously be healthy).

4 The very fact that a decision is difficult usually means that the advantages and drawbacks of the various alternatives are pretty well balanced, so that the net loss cannot amount to much in any event. In such cases it is frequently more important to arrive at some decision — any decision — promptly than to arrive at the best decision ultimately. So take a definite position and see it through.

5 It is futile to try to keep everybody happy in deciding issues involving several incompatible points of view. By all means give everyone a fair hearing, but after all parties have had their say and all facts are on the table, dispose of the matter decisively even if someone's toes are stepped on. Otherwise the odds are that all parties will end up dissatisfied, and even the chief beneficiary will think less of you for straddling the issue.

The following criteria are helpful in choosing a course of action when other factors are indecisive; ask yourself these questions:

(*a*) Does it expedite and progress the undertaking, or does it smack of procrastination and delay?

(*b*) Is it fair and square and aboveboard?

(*c*) Is it in line with established custom, precedence of policy? A good reason is generally required for a departure.

(*d*) Is it in line with a previous specific decision or understanding? Even a good reason for making a change will sometimes not offset the unfortunate impression of apparent instability. "He can't make up his own mind" is a common reaction. (Observe, however, that this criterion is suggested only "when other factors are indecisive." By all means have the courage of your convictions when the change is justifiable.)

(*e*) What are the odds? Can I afford to take the chance? How does the possible penalty compare with the possible gain, in each of the alternatives offered? Very often you can find a solution wherein the worst possible eventually isn't too bad, in relation to the possible gains.

Do not allow the danger of making a mistake to inhibit your initiative to the point of "nothing ventured, nothing gained." It is much healthier to expect to make mistakes, take a few good risks now and then, and take your medicine when you lose. Moreover, there are few mistakes that cannot be turned into profit somehow, even if it's only in terms of experience.

Finally, it should be observed that having "the courage of

[3] See "Definition of an Executive," by H. S. Osborne, *Electrical Engineering*, vol. 61, August, 1942, p. 429.

your convictions" includes having the courage to do what you know to be right, technically as well as morally, without undue regard for possible criticism or the necessity for explaining your actions. Many seemingly embarrassing situations can readily be cleared up, or even turned to advantage, merely by stating the simple, underlying facts of the matter. It boils down to a very straightforward proposition: If your reasons for your actions are sound, you should not worry about having to defend them to anyone; if they're not sound you'd better correct them promptly, instead of building up an elaborate camouflage.

Do not overlook the value of suitable "preparation" before announcing a major decision or policy. When time permits, it is frequently good diplomacy to prepare the ground for such announcements by discussing the matter in advance with various keymen or directly interested parties. This is, in fact, an elementary technique in diplomatic and political procedure, but it is all too often ignored in engineering practice. Much embarrassment and bad feeling can be caused by announcing a major change or embarking upon a new program or policy without consulting those directly affected or who are apt to bring up violent objections, with good reason later on.[4]

HANDLING DESIGN AND DEVELOPMENT PROJECTS

Beware of the "perils of security" in planning your engineering programs. It is one of the fundamental anomalies of human experience that too much preoccupation with the pursuit of security is very apt to lead to greater danger and insecurity. In a competitive world you *must* take chances—bold and courageous chances—or else the other fellow will, and he will win out just often enough to keep you running, all out of breath, trying to catch up. So it behooves you as an engineering executive to "stick your neck out," and keep it out, by undertaking stiff development programs, setting a high mark to shoot at, and then working aggressively to realize your objectives. With competent direction any representative engineering organization will work its way out of a tight spot, every time, under the pressure of the emergency. If you do not like such "emergencies," just remember that, if you do not create your own emergencies in advance, your competition will create them for you at a much more embarrassing time later on.

In order to minimize the risk it is good policy to hedge against the failure of a new project by providing an alternative, or an "out" to fall back on, wherever practicable. You can go after bigger stakes with impunity when you have suitably limited your possible losses in such a manner.

Plan your work, then work your plan. The following formula for carrying out a development or design project seems to be standard in the best engineering circles:

(*a*) Define your objectives.
(*b*) Plan the job, by outlining the steps to be accomplished.
(*c*) Prepare a definite schedule.
(*d*) Assign definite responsibilities for each item.
(*e*) Make sure that each man has sufficient help and facilities.
(*f*) Follow up; check up on progress of the work.
(*g*) Revise your schedule as required.
(*h*) Watch for "bottlenecks," "log-jams," and "missing links;" hit lagging items hard.
(*i*) Drive to a finish on time.

Plan your development work far enough ahead of production so as to meet schedules without a wild last-minute rush. In the nature of things it seems inevitable that the group responsible for design engineering is also in the best position to take care of development projects. This is due to the intimate contacts of the designers with the practical problems of production, performance, and market requirements. But it is also true that very considerable foresight is required to offset the natural tendency of designers to become preoccupied with immediate problems of this nature, at the expense of the long-range development program, which is not so urgent and pressing. It is therefore the function of management to exercise sufficient "vision" to anticipate trends and initiate research and development projects before the demand becomes uncomfortably urgent. This means starting such projects soon enough, i.e., six months, a year, or even two years in advance, to allow sufficient time to carry out all of the necessary steps in a well-ordered program.

Even when the development of new designs simply means a rehash of old fundamentals in new dress, it is important to plan the program early enough and to provide for all stages in the process of getting the product on the market. For example, the following steps may be required to carry through the development of a typical peacetime product:

(*a*) Market survey.
(*b*) Preparation of commercial specifications (features and ratings agreed upon jointly by commercial and design divisions).
(*c*) Preliminary design.
(*d*) Build and test preliminary sample.
(*e*) Final design.
(*f*) Build and test final samples.
(*g*) Preliminary planning and costs.
(*h*) Engineering release of final drawings for production.
(*i*) Final planning and costs.
(*j*) Ordering materials and tools.
(*k*) Preparation of manufacturing and test instructions; application, installation, operating and service manuals; replacement-parts catalogue, publicity releases.
(*l*) Initial production.
(*m*) Test production samples.
(*n*) Minor design changes to correct errors and expedite production.

Obviously, some of these activities can be carried on concurrently, but unless they are all suitably provided for there is very apt to be some awkward stumbling and bungling along the way.

Be careful to "freeze" a new design when the development has progressed far enough. Of course it is not always easy to say how far is "far enough" but, in general, you have gone far enough when you can meet the design specifications and costs, with just enough time left to complete the remainder of the program on schedule. The besetting temptation of the designing engineer is to allow himself to be led on by one glittering improvement after another, pursuing an elusive perfection that leads him far past the hope of ever keeping his promises and commitments. Bear in mind that there will always be new design improvements coming along, but it is usually better to get started with what you have on time, provided only that it is up to specifications as regards features, quality, and cost.

Constantly review developments and other activities to make certain that actual benefits are commensurate with costs in money, time, and manpower. Not infrequently developments are carried along by virtue of Newton's first law of motion long after they have ceased to yield a satisfactory return on the investment. The occasion for vigilance in this respect is obvious enough; it is cited here simply as a reminder.

Make it a rule to require, and submit, regular periodic progress reports, as well as final reports on completed projects. However irksome such chores may seem, your business simply isn't fully organized and controlled until you have established this practice, as regards reports to your superiors as well as from your

[4] See also: "The Technique of Executive Control," by Erwin Haskell Schell. Fifth edition, Book Co., Inc., New York, N. Y., 1942.

subordinates. There appears to be no other regimen quite so compelling and effective in requiring a man to keep his facts properly assembled and appraised.

It is further true that, generally speaking, an engineering project is not really finished until it is properly summarized, recorded, and filed in such a manner that the information can readily be located and utilized by all interested parties. An enormous amount of effort can be wasted or duplicated in any engineering department when this sort of information is simply entrusted to the memory of individual engineers.

NOTES RESPECTING ORGANIZATION[5]

Do not have too many men reporting directly to one man. As a rule, not more than six or seven men should report to one executive in an engineering organization. Occasionally a strong energetic leader will deal directly with fifteen or twenty engineers, in which case he is usurping the positions and functions of several group leaders, burdening himself with too much detail, and depriving the men of adequate supervision.

Assign definite responsibilities. It is extremely detrimental to morale and efficiency when no one knows just what his job is or what he is responsible for. If assignments are not made clear there is apt to be interminable bickering, confusion, and bad feeling. Do not keep tentative organization changes hanging over people. It is better to dispose of a situation promptly, and change it later, than to hold up a decision simply because you might want to change it. It is again a matter of facing issues squarely; it is easier to "just wait and see how things work out" but, beyond the minimum time required to size up personnel, it's not good management.

In so far as possible, avoid divided responsibility for specific functions. Ideally each man should have full authority and control over all of the factors essential to the performance of his particular function. This is commonly expressed in the aphorism that authority must be commensurate with responsibility. In practice this is seldom possible of fulfillment; we must all depend upon the contributions of others at some point in the process. Still the amount of dependency should be kept to the practical minimum, for it is extremely difficult for a man to get anything done if he must eternally solicit the voluntary co-operation or approval of too many other parties. This is what is known as being "organized to prevent things from getting done."

The logical answer to the problem of divided responsibility (or "division of labor") is co-ordination. If any activity, such as the design of a product, must be divided into development, design, drafting, and production engineering, these functions should obviously be co-ordinated by a single responsible engineer.

If you haven't enough legal authority assume as much as you need. During the Civil War a Confederate officer one evening found that his supply train was held up by a single Union battery which was dropping shells accurately into a narrow mountain pass. Without even changing his uniform, he rode around to the rear of the battery, and, coming upon them suddenly, sharply ordered them to swing their guns around to another point. He was obeyed with alacrity because he acted as if he expected to be obeyed. He rode off to rejoin his command, and led them through the pass before anyone discovered that he had exceeded his authority.

Of course such tactics are not recommended for general use, but the story illustrates the fact that quite a lot can be accomplished, on occasions, without full administrative sanction. The important thing is to exercise sufficient care to avoid running afoul of the interests and authority of others.

[5] For a more authoritative discussion of this subject, see the excellent series of papers on "Organization and Management of Engineering," *Electrical Engineering*, vol. 61, Aug., 1942, pp. 422–429.

This injunction is based upon three elementary facts of experience:

1 A man will frequently be held responsible for a good deal more than he can control by directly delegated authority.

2 A very considerable amount of authority can be assumed with complete impunity if it is assumed discreetly, and with effective results. People in general tend to obey a man who appears to be in charge of any situation, provided that he appears to know what he is doing and obtains the desired results.

3 Most executives will be very pleased to confirm such authority in their subordinates when they see it being exercised effectively. Executives in general have much more trouble pushing their men ahead than in holding them back.

Do not create "bottlenecks." Co-ordination of minor routine affairs is sometimes carried too far, when a single individual must pass upon each transaction before it can be carried out. Such rigid control can easily cause more trouble than the original liability. Fortunately, bottlenecks are usually recognized early in the game, and it is easy to avoid them by designating alternates, or by allowing freedom of action in emergencies, with the proviso that the proper party be notified at the first opportunity.

Assign responsibilities for technical subjects, as well as for specific products, in setting up your engineering organization. This is a practice which could be used to advantage in design sections more frequently than it is. The idea is to assign dual responsibilities to each engineer; (*a*) for a particular product or line of apparatus, and (*b*), for a technical specialty, such as lubrication, heat transfer, surface finishes, magnetic materials, welding, fluid flow, etc. These assignments should be made known to all members of the group, with the request that all pertinent material on each subject be referred to the proper specialist, who will act as consultant and as contact man with laboratories, etc., for the entire section. It may, of course, be desirable to assign full-time specialists to important subjects when the business can afford it; the main point is to establish pools of specialized knowledge rather than to expect each designer to know all that he needs to know about the principal arts and sciences which are common to the various products of the department.

WHAT EVERY EXECUTIVE OWES HIS MEN

Promote the personal and professional interests of your men on all occasions. This is not only an obligation, it is the opportunity and the privilege of every executive.

As a general principle, the interests of individual engineers coincide with the company's interest, i.e., there is, or should be, no basic conflict. The question of which should be placed first is, therefore, rarely encountered in practice, although it is clear that, in general, the company's interests, like those of the state or society, must take precedence. It is one of the functions of management to reconcile and merge the two sets of interests to their mutual advantage, since they are so obviously interdependent.

It should be obvious that it is to the company's advantage to preserve the morale and loyalty of individual engineers, just as it is common policy to maintain proper relations with the labor unions. The fact is that attempts to organize engineers into unions have failed simply because the engineers have been confident that their interests have been looked after very conscientiously and very adequately by responsible executives.

Morale is a tremendously important factor in any organization. It is founded primarily upon confidence, and it reaches a healthy development when the men feel that they will always get a square deal plus a little extra consideration on occasions.

Specific injunctions under this principle are cited in succeeding items.

Do not hang onto a man too selfishly when he is offered a better

opportunity elsewhere. It's a raw deal to stand in the way of a man's promotion just because it will inconvenience you to lose him. You are justified in shielding him from outside offers only when you are sincerely convinced that he has an equal or better opportunity where he is. Moreover, you should not let yourself get caught in a position where the loss of any man would embarrass you unduly. Select and train runners-up for all keymen, including yourself.

Do not short-circuit or override your men if you can possibly avoid it. It is very natural, on occasions, for an executive to want to exercise his authority directly in order to dispose of a matter promptly without regard for the man assigned to the job. To be sure, it's your prerogative, but it can be very demoralizing to the subordinate involved and should be resorted to only in real emergencies. Once you give a man a job, let him do it, even at the cost of some inconvenience to yourself. Never miss a chance to build up the prestige of your men. And more than a little mischief can be done by exercising authority without sufficient knowledge of the details of the matter.

You owe it to your men to keep them properly informed. Next to responsibility without authority comes responsibility without information, in the catalogue of raw deals. It is very unfair to expect a man to acquit himself creditably when he is held responsible for a project without adequate knowledge of its past history, present status, or future plans. An excellent practice, followed by many top-flight executives, is to hold occasional meetings of section heads to acquaint them with major policies and developments in the business of the department and the company, so that all will know what's going on.

An important part of the job of developing a man is to furnish him with an ample background of information in his particular field, and as a rule this involves a certain amount of travel. There are occasions when it is worth while to send a young man along on a trip for what he can get out of it, rather than what he can contribute to the job.

Do not criticize one of your men in front of others, especially his own subordinates. This obviously damages prestige and morale.

Also, be very careful not to criticize a man when it's really your own fault. Not infrequently, the real offense can be traced back to you, as when you fail to advise, or warn, or train the man properly. Be fair about it.

Show an interest in what your men are doing. It is definitely discouraging to a man when his boss manifests no interest in his work, as by failing to inquire, comment, or otherwise take notice of it.

Never miss a chance to commend or reward a man for a job well done. Remember that your job is not just to criticize and browbeat your men into getting their work done. A first-rate executive is a leader as well as a critic. The better part of your job is, therefore, to help, advise, encourage, and stimulate your men.

On the other hand, this does not mean mollycoddling. By all means get tough when the occasion justifies it. An occasional sharp censure, when it is well deserved, will usually help to keep a man on his toes. But if that's all he gets, he is apt to go a bit sour on the job.

Always accept full responsibility for your group and the individuals in it. Never "pass the buck" or blame one of your men, even when he has "let you down" badly, in dealings with outsiders. You are supposed to have full control and you are credited with the success as well as the failure of your group.

Do all that you can to see that each of your men gets all of the salary that he's entitled to. This is the most appropriate reward or compensation for outstanding work, greater responsibility, or increased value to the company. (Any recommendation for an increase in salary must be justified on one of these three bases.)

Include interested individuals in introductions, luncheons, etc., when entertaining visitors. Obviously, this can be overdone, but if you're entertaining a visiting specialist, it is good business, as well as good manners, to invite the corresponding specialist in your own department to go along.

Do all that you can to protect the personal interests of your men and their families, especially when they're in trouble. Do not confine your interest in your men rigidly within the boundaries of "company business."

Try to get in little extra accommodations when justifiable. For example, if you're sending a man to his home town on a business trip, schedule it for Monday, so that he can spend Sunday with his family, if it makes no difference otherwise.

Considerations of this sort make a "whale" of a difference in the matter of morale and in the satisfaction an executive gets out of his job. The old-fashioned "slave driver" is currently regarded in about the same light as Heinrich Himmler. Treat your men as human beings making up a team rather than as cogs in a machine.

In this connection, it is sometimes advisable to talk things over with a man when you become definitely dissatisfied with his work, or recognize a deficiency which is militating against him. To be sure, it is not always easy, and may require much tact to avoid discouraging or offending the man, but it may well be that you owe it to him. Bear this in mind; if you ultimately have to fire him, you may have to answer two pointed questions: "Why has it taken you five years to discover my incompetence?" and, "Why haven't you given me a fair chance to correct these shortcomings?" Remember that when you fire a man for incompetence, it means not only that he has failed, but also that you have failed.

(To be continued)

Courtesy Glenn B. Martin Co.

BOMBER LANDING GEAR

ENGINEERING EDUCATION AFTER THE WAR

A Report of a Committee of the S.P.E.E.

ENGINEERING education, in common with all other activities of the Nation at present, is being powerfully influenced by the war. Many of these influences are likely to continue into the period of readjustment that will follow. It is even possible that some of them may be lasting and that the pattern of engineering education may thus be permanently modified. The whole realm of higher education is in a state of flux. During such a period conditions susceptible of control may be so misjudged as to be permitted to cause lasting damage. On the other hand, they may be so controlled as to avoid injury or so guided as to yield permanent benefits. It was considerations such as these that led to the appointment of this committee.

The committee has been directed to study the urgent problems of the immediate future as well as longer-range problems of educational principle and practice, and particularly to review the 1940 Report on Aims and Scope of Engineering Curricula[1] in the light of future conditions as they can now be envisaged. The committee has been directed specifically to study the need, as made clear by the issues of the war, of creating among engineers an understanding of the social and economic world they live in and have had so large a share in creating.

The 1940 Report on Aims and Scope of Engineering Curricula advocated the strengthening of engineering education by concentration on basic elements in the undergraduate years, organization of the curriculum in parallel integrated sequences of scientific-technological and humanistic-social subjects, and by transfer of some of the more specialized subjects to the postgraduate period.

The exigencies of war have tended to cause a reversal of the process embodied in these recommendations. Special war training programs of limited duration must necessarily be concentrated on the attainment of specific technical objectives. Even their basic phases include only such general studies as have a direct relationship to military requirements. No one will question the necessity of training men for military service by intensive methods in time of war. We believe, however, that with the cessation of hostilities the policy of expediency in engineering education should be abandoned. The evolutionary process of strengthening engineering education at its base should then be resumed as quickly as possible.

In attacking its assignment the committee considered, first, matters of general policy. These are discussed in Part I of this report.

Specific problems of the postwar period are then considered in Part II. These include the adjustment of curricula to the needs of returning veterans, the adaptation of the college calendar to the postwar transition period, the possible effects of future universal military service, the rehabilitation of faculties, the restoration and strengthening of postgraduate study and research, and the study of lessons learned from war experiences that may be applied to the permanent benefit of engineering education.

The committee comprises 21 members and has held two general meetings. A smaller group of members has met at other times to prepare drafts of the report. These have then been reviewed by the entire committee. A version prepared by this process has been circulated among a large group of educators both in and outside of engineering education. The report, therefore, is the result of a long process of preparation and embodies the ideas of many persons.

The committee recognizes that a report can do no more than discuss problems, state principles, and make recommendations. It remains for the great body of those who conduct engineering education or are interested in it to take action. The committee earnestly hopes that one of the chief results of the report will be to stimulate discussion of the matters here presented at meetings of college faculties and professional engineering societies, and that the results of such discussions may be disseminated widely.

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H. P. Hammond, *Chairman*

I PURPOSES AND PROBLEMS OF ENGINEERING EDUCATION

The purposes and problems of engineering education hinge on its two major responsibilities. One of these, which determines its aims and standards, is to the public, industry, and the profession it serves. The other, which determines its methods, is to the students as indiviudals. It is responsible to the public for seeing to it that the students emerge from college with an attitude and background appropriate to effective citizenship as professional men, and that they shall have acquired a sustaining interest in the common welfare and the cultural aspects of community life. Engineering education is responsible to industry for educational programs suitable for professional personnel in engineering and management, and to the engineering profession for the maintenance of proper educational standards and the inculcation of ethical attitudes and conduct among its graduates. Finally, it is responsible to the students themselves for an educational program in which they will be treated as individuals and helped to achieve maximum development of mind and character.

The specific purposes implied here are of broad scope and are essentially those recommended in the 1940 Report on Aims and Scope of Engineering Curricula. They include training in the sciences basic to engineering, the rudimentary development of certain technical skills, an introduction to the engineering method of solving problems of practice, an understanding of values and costs, a sense of the art of engineering as distinguished from its science, the ability to read, write, and speak the English language effectively, a knowledge of social and human relationships, an understanding of the duties of citizenship, an appreciation of cultural interests outside the field of engineering, and indoctrination in professional standards and relations. Inherent in the accomplishment of these purposes is

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the development in the student of habits of accuracy and thoroughness, powers of analysis, creative ability, respect for facts, and high standards of integrity with respect to all aspects of his work.

Among the problems involved in the accomplishment of these purposes, perhaps the most difficult one is the limitation of time, especially in view of the conditions set at the beginning and the end points of the curriculum.

On the one hand, the level of beginning is set by the secondary schools. While efforts are being made to insure more adequate preparation of students and greater selectivity in admitting them, the early stages of the undergraduate curriculum are likely to continue to be essentially introductory in nature; the early semesters will have to be directed to an important extent to developing ability to study effectively, to think quantitatively, and to execute systematically. Experience in the Army and Navy training programs has disclosed that even when students are selected on the basis of high scholastic aptitude the necessity remains of devoting a great deal of time and effort to adjusting them to the conditions of collegiate study, especially in science and engineering.

On the other hand, the terminal point is set by the obligation assumed by engineering schools themselves that by the time of graduation their students will have achieved the knowledge, abilities, and attitudes referred to above. To help the student, starting at the high-school level, to achieve these ends within the time available, imposes a problem that can be solved only by the most careful planning in which the strictest attention is given to the adopted objectives and only such subject matters and procedures are included in the curriculum as are essential to their attainment.

The above paragraphs and the 1940 Report identify the purposes and problems of engineering education as a whole and indicate for the great body of engineering students goals that seem possible of attainment in the near future. We feel justified, however, in going a step further by discussing certain trends that seem to point to the adoption of additional modifications of educational programs, as soon as may be practicable, for certain special groups of students. One of these trends is the increase in the application of the engineering method in the management and operation of industry as evidenced by the phenomenal increase in the use of engineering graduates in these fields of activity. A second clearly evident trend is the greatly increased need for engineers prepared to practice at high scientific and creative level. It is a matter of vital concern to the nation in relation both to security and economic welfare that the highest levels of scientific and engineering excellence be maintained at all times. We believe that the special needs of students to be prepared for service in accordance with these trends should be met by provision of curricula different from those offered for the great majority referred to above. Thus plans should be laid for three major groups of students:

1 Those who would follow engineering programs of the usual pattern, but modified as indicated elsewhere herein and in accordance with the objectives of the Report of 1940. This group would continue to comprise a majority of undergraduate engineering students.

2 Those preparing for careers in the operation and management of industry.

3 Those who would be fitted for unusual scientific and creative accomplishments.

Curricula provided for all three groups should possess the elements that are common to all genuine engineering programs, that is, emphasis on the engineering method and sound preparation in physical science and engineering fundamentals. Without these elements a program does not belong in a school of engineering.

For all of the programs mentioned, we believe that the first three years should conform to customary patterns, modified in general characteristics as suggested elsewhere in this report, and with variations in subject matters of physical and engineering science in accord with the several major branches of engineering. After the third year, however, more fundamental differentiation would begin. For the first two groups—regular students and the industrial group—professional subject matter would be different in nature and functional purpose. The industrial group would give major attention to matters relating to production and operation, while the regular group would concentrate on scientific-technological studies. The content of humanistic-social studies would be the same for both groups as would the total duration, generally four academic years, required for the award of the baccalaureate degree.

The program for the group preparing for highly scientific and creative engineering work should be differentiated from the other programs not later than the end of the junior year in order to provide broader and more fundamental preparation in scientific principles and methods than is needed for the general run of students. This program would of necessity be longer in duration than the others and would extend from the end of the junior year through one or more years of graduate study leading to the master's or doctor's degree. The curriculum should be *planned as a unit* comprising two or more years and thus requiring for completion a total of at least five years from time of admission to college. This program is referred to again under "graduate work."

It may be well at this point to review the purposes of engineering education which we reaffirm, as recommended in the Report of 1940. Two major divisions are to be recognized: (1) the scientific-technological and (2) the humanistic-social. The objectives of the scientific-technological division are:

1 Mastery of the fundamental scientific principles and a command of basic knowledge underlying the branch of engineering which the student is pursuing. This implies:

(*a*) Grasp of the meaning of physical and mathematical laws and knowledge of how they were evolved and of the limitations in their use;

(*b*) Knowledge of materials, machines, and structures.

2 Thorough understanding of the engineering method and elementary competence in its application. This requires:

(*a*) Comprehension of the interacting elements in situations which are to be analyzed.

(*b*) Ability to think straight in the application of fundamental principles to new problems.

(*c*) Reasonable skill in making approximations, and in choosing the type of approach in the light of the accuracy required and the time available for solution—in sum, a foundation for engineering judgment.

(*d*) Resourcefulness and originality in devising means to an end.

(*e*) Understanding of the element of cost in engineering and the ability to deal with this factor just as competently as with technological factors.

3 Ability to select the significant results of an engineering study and to present them clearly and concisely by verbal and graphic means.

4 Stimulation of a continuing interest in further professional development.

The objectives of the humanistic-social division are:

1 Understanding of the evolution of the social organization within which we live and of the influence of science and engineering on its development.

2 Ability to recognize and to make a critical analysis of a problem involving social and economic elements, to arrive at an intelligent opinion about it, and to read with discrimination and purpose toward these ends.

3 Ability to organize thoughts logically and to express them lucidly and convincingly in oral and written English.

4 Acquaintance with some of the great masterpieces of literature and an understanding of their setting in and influence upon civilization.

5 Development of moral, ethical, and social concepts essential to a satisfying personal philosophy, to a career consistent with the public welfare, and to a sound professional attitude.

6 Attainment of an interest and pleasure in these pursuits and thus of an inspiration to continued study.

Experiences of the war have in no way altered our belief in the validity of organization of the undergraduate curriculum in two parallel stems embodying these divisions of study and subject matter and co-ordinate in their bearing on the student's total development.

MEANS OF ACHIEVING THE PURPOSES OF THE CURRICULUM

It is not sufficient, however, merely to recognize the purposes of these two curricular stems; it is necessary also to establish the *means* for achieving their educational objectives. Explicit objectives must be formulated not only for the major portions of the curriculum but also for each of its subdivisions in terms of knowledge to be acquired and abilities to be achieved. The committee realizes that no existing formulation of means—of educational programs and procedures—has as yet proved to be fully adequate in achieving these objectives. We believe that a year-by-year development of such means is one of the most important tasks before this society. A few suggestions are proposed as a preliminary basis for the *design of a plan* for guiding the student's development.

Division of Time. One suggestion relates to the allocation of the student's time as between the scientific-technological and the humanistic-social stems of the curriculum. While it is clearly recognized that the scientific-technological studies must receive a preponderant allotment of time, it is also evident that adequate time must be allocated to the humanistic-social studies if the objectives are to be reasonably well achieved. We believe they cannot be achieved through a three-hour course in English in the freshman year plus a three-hour course in economics in the sophomore year; that they can be achieved only through a *designed sequence* of courses extending throughout the four undergraduate years and requiring a minimum of approximately 20 per cent of the student's educational time. This allotment should be at least equivalent to one three-hour course extending throughout the curriculum, and on the average somewhat more.

THE HUMANISTIC-SOCIAL STEM

Methods of Organization. The positions taken in the 1940 Report constitute a definite collective judgment on the goals of the humanistic-social area of engineering education. If, as is now suggested, the equivalent of about one academic year is allotted to this area, it will mark a substantial advance in most engineering curricula. None the less, the result even under favorable conditions seems likely to be somewhat less adequate than in other areas.

It may be appropriate, therefore, to summarize in as pointed terms as present experience will sustain the conditions which may make for the most effective result within the limits of time and personnel available:

1 *Establish responsibility* for planning and co-ordination; merely parceling out time to isolated departments has generally led to unsatisfactory results. If responsibility cannot be established through the customary type of department headship, it may be necessary to do it through administrative direction, at least until the aims of the program are recognized and the work soundly established. A similar focal point of responsibility in the humanistic-social area is needed in this society.

2 *Formulate the results sought* as explicitly as possible; select appropriate materials with discrimination; and arrange them in a unified, developing sequence extending through the curriculum.

3 *Discriminate between humanistic studies and business training.* Economics, sociology, government, history, and psychology are sciences of human behavior and relations, while accounting, for example, is a technical subject closely related to engineering cost analysis.

4 *Allot time in more advanced years* as generously as possible. The interests of engineering students are likely to center on technical subjects in the earlier years. As they become more mature in later years their interests in social, cultural, and philosophical matters are, we believe, more readily aroused and developed.

5 *Enrich this area of work* by use of whatever time may be gained by individuals or groups through entrance levels in mathematics, science, drawing, and ordinary language skills.

6 *Use the most skillfull teaching available.* Erudition is a secondary consideration; mental maturity, perspective, sympathetic perception of the student's present viewpoint and of his career aims, interpretive ability, and ability to awaken interest and elicit active participation are primary. The teacher must exemplify the matters he teaches in traits of personality and in personal competence.

7 *Capitalize on the appeal of current interest.* Many engineering students, especially in early years, are more readily interested in contemporary literature than in the classics and respond better to the history of the modern world than to the evolutionary history of scientific ideas or of social and political institutions.

8 *Reinforce curricular work by voluntary student activities.* Encourage engineering students to participate in expressional activities (music, dramatics, public speaking, painting, etc.) and in student organizations concerned with public and social problems; provide organized opportunities for attending the theater, concerts, art exhibits, etc., and assign themes and reviews based on these events.

Responsibilities of Citizenship. The duty of citizenship in a democratic society is one which an engineer may fulfill in part as an individual and in part through his participation in the group activities of his profession and community. The training and experience of his student days should lay foundations for both types of competence. It seems clear that engineers, as part of this professional duty, must assume a more important share in shaping public policies and practices, and especially so in areas related to their work.

Among the roles of citizenship, four aspects may be recognized:

1 Observance of laws and regulations.
2 Sustaining participation in government and in cultural activities.
3 Criticism and counsel.
4 Creative contributions as statesmen, thinkers, artists, philanthropists and leaders of social movements.

Obviously engineers will not assume the more conspicuous critical and creative roles except in relatively few cases. On the other hand, engineers should be counted in full proportions among groups which read books, discuss ideas, hear music, attend the theater, appreciate works of art, sustain churches, advance philanthropy, man welfare activities, serve as trustees, and lead civic movements.

The acquisition of definable knowledge, while not the primary means to this end, is in no sense unimportant. It is not too much to expect the engineer, in addition to a satisfactory level of general literacy, to have an elementary critical understanding of the philosophy of the democratic state and of the economics of private and public enterprise, and an appreciation of the contributions of science and technology to industrial progress and the general welfare. He should also, as a guide to critical, ethical, and moral values, have some acquaintance with the great enduring humanistic ideas which men have evolved.

Attitudes, emotions, feelings, and beliefs are among the primary forces motivating conduct and behavior. These are obviously the fruit of nurture and indoctrination, but may be brought to effective maturity as they are refined by critical thought, by experience, and by faith. The role of the college in these processes of nurture and refinement, while not easily defined, is none the less real and insistent. The natural detachment so desirable in science will not suffice in the humanities nor in certain of the social studies, where concepts of value and motivation of social conduct are involved.

These concerns can be expressed only partially in the curriculum. Continuous cultivation by precept, by example, and by participation in campus activities of civic value deserves equal emphasis.

Program and Methods of Instruction. While the selection of subject matter suitable to the achievement of the aims of humanistic-social studies is important, we believe that this will present less difficulty than will devising appropriate methods of instruction.

The subjects usually, and we believe properly, associated with the humanistic-social stem of the curriculum are found in the fields of history, economics, and government, wherein knowledge is essential to competence as a citizen; and of literature, philosophy, psychology, and fine arts which afford means for broadening the engineer's intellectual outlook. Any particular program must of necessity be built within the framework of conditions which can be established and with the personnel available.

We believe, however, that knowledge of miscellaneous details of the subject matter selected is less important for engineering students than is the acquirement of the ability to understand, to analyze, and to express the essentials of an economic, social, or humanistic situation or problem, and to appreciate the implications and relationships of such problems to the life and work of an engineer.

Formal expository methods are often used in these fields. We believe they are less effective in accomplishing the results advocated than a method which places responsibility on the student himself. Such a method should require him to read, to question, to seek evidence, to weigh, to judge, to accept, and to express the results of his efforts in written or oral form both in school and in life situations. It will also require greater effort and skill on the part of the instructor as well as a more generous allotment of assigned teaching time than is customarily given to this portion of the curriculum. Finally, it will require careful nurture and direction on the part of both faculty and administrative leaders.

THE SCIENTIFIC-TECHNOLOGICAL STEM

Emphasis in Curriculum Organization. The mere enumeration of the aims and purposes of engineering education makes clear the difficulty of achieving them in the limited time available with young men of varied preparation and capacities who have inadequate general knowledge of the nature of engineering. The inference is plain that the entire educational program must be scrutinized with the view to eliminating all unimportant elements and concentrating on those of primary importance. It is especially clear that the attempt to make the undergraduate student proficient in specialized subdivisions of engineering practice must be abandoned in the interests of developing mastery of basic principles.

The 1940 Report on Aims and Scope of Engineering Curricula presented, and this committee reaffirms, the following general recommendations for carrying the foregoing proposals into effect:

> Undergraduate curricula should be made broader and more fundamental through increased emphasis on basic sciences and humanistic and social studies. This will require greater efficiency in the use of the student's time to be gained by pruning to the essentials of a sound educational program.
>
> Some of the advanced technical subject matter now included in undergraduate curricula should be transferred to the postgraduate period where it may be pursued with a rigor consistent with preparation for engineering specialization.

Tools of Scientific-Technological Thought. A sound program of objectives for scientific-technological studies must include both the development of mastery of the fundamentals and rudimentary facility in their application. These two associated elements—critical understanding and power of constructive application—are complementary. One may not possess either in any considerable degree without the other.

We believe that the attainment of mastery of fundamentals is influenced greatly by the proper selection of subject matters, while the development of power to apply them is influenced most by the method of instruction. It must be recognized that this mastery and power are not separate entities but different aspects of the same thing—the process of engineering thought.

The evolution of engineering thought and of engineering practice has given us a body of knowledge based upon facts and principles that may be classified in five broad categories:

1 *Generic principles*, including such basic concepts as the law of conservation of energy.

2 *Basic assumptions*, such as "plane sections before bending remain plane after bending," which are made for the purpose of simplifying the mathematical analysis of physical phenomena.

3 *Empiricisms*, such as the properties of materials which have been observed and measured in the laboratory.

4 *Derived principles*, or working formulas, such as the flexure formula, which have been developed in various fields of practice.

5 *Specifications and standards, or codes of practice.*

These principles, assumptions, empiricisms, standards, and practices are the working tools of the engineer. They are presented in courses which differ in their emphasis. Generic principles and basic assumptions are traditionally presented in such fundamental courses as physics, mechanics, hydraulics, electrical circuits, and thermodynamics. Critical understanding of them rests primarily upon *recognition of their underlying physical concepts*. These are frequently so obscured by the presentations of textbooks and teachers that students may accept them merely as algebraic statements or formulas to be remembered. There is great opportunity to vivify the presentation of these concepts through graphical methods and laboratory demonstrations. It is essential that major principles and concepts *be presented in connection with physical situations* in such a way that the student will learn to recognize the elements of similar situations that are new to him and thus be able to identify the principles that are involved. There are relatively few such principles and concepts but they are applicable to problems in many fields. We believe that an appreciation of this underlying unity in the field of physical science is essential.

Empiricisms are best presented and studied in the laboratory. Most of them have definite limitations within which they may be applied. It is very important that students understand the origin and limitations of empirical data and principles.

Derived principles and specifications and standards have evolved in the development of technology and of the arts of engineering practice. They are generally presented in such applied courses as electrical machinery, heat power, and structural design. While the emphasis in basic courses should be upon critical understanding, in applied courses emphasis should shift toward facility in the use of derived principles. It is most essential, however, that even here students thoroughly understand the origin and limitations of working data and formulas. In using a formula he should be required to identify the principles and assumptions from which it was derived.

In the long run, however, facility in the application of principles, either generic or derived, to the solution of new problems is based upon a critical understanding and a conscious recognition of these tools of engineering thought. No other one thing ties the engineering profession more closely together than this way of thinking.

The Art of Engineering. The subdivisions of knowledge enumerated above constitute the subject matter of engineering study. Knowledge of these tools, however, does not constitute ability to practice engineering. There remains the necessity for the young engineer to integrate the application of these laws, assumptions, data, and codes so as to accomplish a desired result safely and economically. This requires a combination of resourcefulness, skill, experience, and judgment—amounting at times almost to intuition—which we call the *art* of engineering. Judgment matures only through experience, but introduction to the art of engineering and the development of judgment—in other words, elementary competence in the engineering method—can and should begin in college. Unless instruction includes the elements of the arts of practice, it will be in science rather than in engineering. Throughout the whole fabric of engineering education, therefore, there must be interwoven with scientific principles the development of rudimentary skills

of execution, understanding of the limitations in the application of principles to practical situations, the beginnings of powers of decision and of judgment, the encouragement of creative talent, ability to deal with the factor of values and costs, and the acquirement of that appreciative sense which is satisfied only by skillful execution or precise verbal expression.

The significance and nature of the art of engineering practice cannot be conveyed completely in any single subject of instruction; it should be inherent in greater or less degree in all engineering courses. In advocating the broadening and strengthening of the scientific and humanistic base of engineering education we are equally conscious of the need to retain and enrich this element in the education of engineers.

Instructional Procedures. Methods of instruction will and should vary with individual teachers, but certain common characteristics of sound instructional methods in engineering can be identified. Some of these characteristics are here stated with the purpose of stimulating further discussion:

1 Engineering education possesses the great advantage of employing three processes of instruction: lecture-recitation, laboratory, and design. The advantages of each should be capitalized. When two or more methods are employed in a given division of subject matter they should be co-ordinated. Advantages to be gained by treating a given subject in a single unified course are often lost when the work is handled in separate recitation, laboratory, and design courses.

2 In engineering, learning is best achieved by doing. Knowledge acquired by merely being receptive to the efforts of the teacher is not likely to be permanent. The process of "having the teacher recite the lesson for the class" is a poor method of instruction. The problem method is most effective for the mastery of elementary principles, and the project method for the integration of thought procedure and of practice in the development of the art of engineering.

3 Dealing with students individually is more effective than dealing with them in groups. Correction of individual mistakes, overcoming individual weaknesses, developing individual strengths—a process possible only when class sections are relatively small and instructors' loads reasonable—is conducive to better results than less individual methods. However, the provision of small sections and light loads merely creates the conditions under which good instruction can be given. Observation indicates that the lecture method is used almost as often in small classes as it is in large ones. Unless the individual teacher takes advantage of the opportunities for individual instruction that small class sections afford the extra cost is wasted.

4 Each course should be designed as an integrated whole, not as a mere assembly of loosely related subject matters. And it should be closely related in content and method to other courses in the same general field.

5 Students should be acquainted with the reasons for each course and its purposes at the beginning, and means should be afforded to them to appraise their own achievement of those purposes. Progress toward mastery and competence should be recognized and rewarded.

Instruction in the Engineering Method. The engineering method should be emphasized in all scientific-technological courses. However, in many of them it may be lost sight of by being subordinated to subject matter. The engineering method implies a breadth of understanding which it is difficult to develop to the fullest in a course devoted to a specific subject. Hence there are advantages to be gained in a course having as the *primary purpose* the development of a method of approach, and in which the situations to be analyzed are not restricted to a single subject, but involve several fields. At this point the report includes a description of an existing course, Engineering Analysis, which has this purpose and is, in effect, an introduction to the engineering method. This description has been omitted.—EDITOR.

Discipline in Engineering Habits of Work. In most instances, students entering upon engineering study must first learn to work, that is, to study and to execute. While the student is acquiring this ability the teacher must control the process. Assignments must be short range and problems should usually involve only a single principle. At the outset, disciplinary training to establish habits of industry, thoroughness, orderliness, and accuracy is no less important than the study of new fields of subject matter. As the student progresses from term to term the degree to which he can be expected to accept responsibility and exercise his own initiative should increase and closeness of supervision should change correspondingly. Toward the end of the curriculum the student should be able to walk by himself along the educational path—and he should be expected to do so. This implies that as the student advances, work assignments should become progressively more comprehensive. Toward the end of the curriculum problems should attain the dimensions of projects. The process employed in architecture wherein the student works on problems of design of increasing complexity might well be employed to a greater extent in engineering. This method of instruction is more difficult for the teacher than the method of day-to-day assignments, and it is likely to consume more of the student's time. We are convinced, however, that it will lead to better mastery of subject matter and greater self-reliance and initiative.

Cultivation of Creative Ability. The development of creative ability is largely neglected as an explicit objective of engineering education. We believe it should have a recognized place in the undergraduate curriculum. Design courses of the project type and the undergraduate thesis are especially appropriate for this purpose. The fostering and development of initiative and originality should not be limited, of course, to any particular phase of the curriculum. It should be an objective of all engineering instruction.

We suggest that means of promoting creative ability be made a matter for consideration by the society and that it be discussed both in committee and in general meetings.

Measurement of Achievement. The committee urges the setting up of standards of proficiency based on achievement of defined objectives. At the end of each course and of each division of the curriculum the degree to which the student has *achieved his objectives* should be carefully measured. Such measurements will differ from the usual course examinations; in accordance with the objectives, they will test to a lesser degree retention of subject matters and miscellaneous formulas, and to a much greater degree understanding and the ability to *do*, i.e., to think one's way through, to complete a project, to express a thought. Thus as the student progresses, the measurement of his achievement should become increasingly comprehensive, involving projects of greater scope which tax his creative powers and initiative. Such standards of proficiency will place less emphasis upon extent of subject matter covered; they will emphasize mastery and power to perform independently.

Recruitment and Development of Faculties. Realization of the objectives of this report will depend in large measure on the effectiveness of engineering faculties. The rehabilitation of these groups from the impairment caused by war is discussed elsewhere in this report (see Part II). However, there are other factors relating to the effectiveness of teaching staffs that are not dependent upon war conditions.

First of these in importance is the necessity of painstaking selection of teachers of all age levels and ranks. While care is usually exercised in choosing teachers for the higher faculty posts, instructors and assistants are appointed too often on the basis of expediency instead of the criterion of eventual development to fill important positions. Whether or not the principle of tenure is applied in the best interests of faculty effectiveness, it is a condition to be reckoned with, and appointments should be made with the possibility of permanency in mind. Good administrative practice will aim to insure a steady progression of able young men from among whom higher faculty positions can be filled as vacancies occur or new positions are created.

During the decade immediately preceding the war, increasing numbers of able students were pursuing graduate courses in engineering. An abundant supply of promising teachers was be-

ginning to be available from this source and there was prospect that in comparatively few years better engineering faculties would be assembled than ever existed before. It is of the utmost importance that this situation be re-established at the earliest possible moment. In the meantime, it is important that long-term appointments be made only of those who could qualify under the most favorable conditions of faculty recruitment that may be created in the future.

A second need is for the systematic development of skill in teaching among younger faculty members and the creation of opportunities for broadening the experience of those whose professional environment has been limited to the classroom and the teaching laboratory. Too often this is a neglected phase of faculty development.

While this committee cannot lay down patterned procedures for accomplishing these tasks, we would emphasize that it should be accepted as the responsibility of engineering-college administrators to establish and direct programs of orientation and development for new and younger members of faculties and to aid in securing opportunities for faculty participation in broadening professional practice.

Instruction and Research as Complementary Phases of the Work of Engineering Colleges. Institutions of higher learning should serve two purposes: (1) Instruction in the existing knowledge of science and the arts, and (2) creation and dissemination of new knowledge. These two purposes are of comparable importance and should be served with equal effectiveness in engineering colleges. These institutions, collectively, should serve as the chief agency for the training of research workers in applied science and for conducting basic technological research. They should also supply research services for industries that do not provide their own research facilities.

Research in engineering colleges is important also as a means of developing a creative environment for the student and a spirit of inquiry and powers of originality among members of the faculty which will be reflected in the classroom.

While instruction in engineering colleges has advanced in this country to a position of recognized strength, an equally strong development of research has been accomplished in relatively few institutions. This is one of the most serious shortcomings of the entire realm of engineering education. It is one to which all concerned should address themselves as soon as normal educational conditions are re-established.

In reference to one aspect of research activities as a function of engineering colleges we would repeat one cautionary statement often made before, namely, that genuine research in engineering and science is one thing, routine testing is another. Routine testing which has no scientific interest and does not promote the qualifications of the individuals concerned but is merely conducted for remuneration should have no place in the work of an engineering college, unless, of course, some definite obligation exists, as on the part of a publicly supported institution to some other public agency, or unless no other testing facilities are available.

Cultivation of the Ideals and Obligations of the Engineering Profession. The cultivation of professional ideals and obligations is assuming increasing importance in the education of engineers because of the growing organization of society into functional groups. Among the characteristics of professional indoctrination the following may be discerned:

Consciousness of the engineering fraternity as a functional group in society engaged in constructive work of a common nature, using a common method of thought, and inheriting common obligations.

Appreciation of the heritage of knowledge and art, of standards of performance, and of the traditions of group action for professional development.

Recognition of the confidential relationship between agent and client, of the principle of fair play between colleagues, and also of the encompassing social duty to the public of service adequately and honestly given.

Loyalty to the principles of professional ethics not alone according to the canons in which they have been formulated but also according to the spirit in which they have been conceived.

Obligation to serve the profession in the advancement of its science, technology, and art, and also in the discharge of its broad social duty.

To the partial achievement of these ends engineering societies and state registration boards have promulgated standards of qualifications and of conduct. Beyond these, however, there rests the moral obligation upon any great professional group to place excellence above quantitative considerations, loyalty above individual aspirations, and service above personal gain.

Out of such points of view and attitudes will grow pride in belonging to the professional group, devotion to the ideals which it advocates, and acceptance of the obligations it has inherited and recognizes.

Engineers' Council for Professional Development is engaged in a program for the development of such a professional consciousness. Engineering faculties have the chief opportunity to carry this program into effect among engineering students. Through their efforts, with the assistance of the national engineering societies, and the S.P.E.E., substantial progress toward the objectives just stated should be increasingly realized.

GRADUATE WORK

The increasing needs for men of advanced engineering training demand attention in educational planning. These needs are indicated by industry's call for such men and by the increasing emphasis laid upon such training by colleges in their search for engineering teachers. We believe these needs can best be met by the plan already outlined under "Purposes and Problems of Engineering Education" in which the last undergraduate year and one or more postgraduate years would be planned as a unit. The undergraduate years would lay the foundation of fundamentals in science and engineering, and of a social philosophy, effective expression, and reflective and critical thought, in accordance with the 1940 Report. Graduate study would build further upon this foundation by a rigorous treatment of advanced engineering science. Moreover, our concept of the relationship between undergraduate and graduate work assumes the adoption of the committee's recommendation that some of the more advanced technical studies now included in undergraduate curricula be transferred to the postbaccalaureate period.

We recognize, of course, that there are practical factors which will make the wide adoption of the above unit plan a process of evolution. For example, undergraduate work at one institution may not now articulate well with the graduate work at another. Also, students who have taken the *regular* undergraduate program will then decide to go on with graduate study. Thus it will take time to develop the plan, but we urge its development.

The program of graduate work that we envisage involves a transition, begun in undergraduate years, from closely prescribed course work to independent study and research. It will not be pursued by continuation of the customary undergraduate method of specific course requirements. Graduate work of this nature requires teaching ability and leadership of high order as well as first-class physical facilities. It cannot be conducted properly where these necessities are lacking. An adequate program of graduate work is costly in comparison with undergraduate work. Many opportunities are afforded in programs of graduate work for close affiliation with basic and industrial research projects. These will lead directly to the production of industrial research workers as well as the highly qualified personnel required in advanced engineering practice.

Another plan of proved effectiveness by which the needs can be met is part-time graduate study by young engineers employed in centers of industry. This is one of the most beneficial developments of engineering education in recent decades. An important fraction of all graduate enrollments in engineering just before the present war was in part-time courses conducted in a

few of the larger centers of population. Means were thus afforded for many young engineers to pursue graduate work who could not afford the time or money to do so in full-time programs; they were enabled to round out their education, especially in fields of interest developed in their regular employment.

We believe that the postwar expansion of graduate work should be strongly encouraged wherever well-qualified personnel can be assembled. In university centers apart from major industrial communities, the necessary means will include increased numbers of graduate scholarships, assistantships, and fellowships, in association with expanded research activities. Institutions in favorable localities should be expected to expand their research activities and programs of advanced training in close co-operation with industries and professional societies. We are convinced that the more complete developments of such programs will not only serve the direct interests of industry and the engineering profession, but will also contribute in a marked degree to the fuller realization of a sounder and broader type of undergraduate education, through relieving pressure of time and enabling engineering teachers to find scope for their specialized interests at a more advanced level.

SUBPROFESSIONAL TECHNOLOGICAL EDUCATION AND TRAINING

War conditions have furnished a striking demonstration of the need for technological training of intensive nature, at a level between that of the vocational and secondary schools and that of the engineering colleges. Faced with a critical shortage of technically trained personnel for service in defense industries, the Federal Government established, late in 1940, the Engineering Defense Training Program of the United States Office of Education as a means of supplying this deficiency. Since then, more than 1,500,000 persons have enrolled in the short, intensive courses of this program, which is now called the Engineering, Science, and Management War Training Program. While these courses are of "college grade," as prescribed by the appropriation acts, their chief purpose has been to train assistants and thus to release engineers, scientists, and industrial managers for more important technical and supervisory activities. While the quantitative need for personnel at all levels of technical pursuits is not as great in times of peace as it is in times of war, the *relative* need remains substantially the same, and educational facilities for work at various levels should exist in similar proportions.

The report on the Study of Technical Institutes, published by this Society in 1931, indicated the lack of an adequate system of technological educational programs of intermediate or subprofessional type.

Lack of recognition of such programs on the part of industry, the engineering profession, and the public at large, and of the place they should occupy in the broad field of preparation for technological pursuits is in large measure responsible for this condition. The situation that exists in the United States is unique in this respect among important industrial nations. Not only in the older educational systems of Great Britain and Germany, but also in the newly created system of the Soviet Union, programs of technical training at intermediate levels far outnumber those at collegiate level. It is said that in U.S.S.R., in 1938, there were 3400 technical institutes of intermediate grade enrolling 700,000 students. In those countries, therefore, there is a much closer relationship between training facilities and industrial needs than exists in our own country, and much more adequate recognition is given to them than is accorded here. Several independently conducted studies have indicated that from three to six times as many persons are needed as draftsmen, inspectors, laboratory technicians, minor industrial supervisors, and the like than are needed as engineers and industrial managers. These studies have indicated also that the technical needs of many positions in the subprofessional categories can be supplied more appropriately by briefer courses than the four-year college-degree program. Yet the relative numbers of individuals trained for subordinate technical positions in this country, in comparison with engineering graduates, are in reverse proportion to the need.

The inevitable result of this situation is to cause industries to seek engineering graduates in large numbers to fill positions for which briefer, less fundamental, and more practical types of training programs would provide more suitable preparation. The result is also to cause many young men to enter engineering colleges who would profit better by pursuing educational programs designed to equip them for more immediate usefulness in the numerous types of industrial pursuits illustrated by the examples given above. The general result of this situation is to cause confusion of aims, purposes, and content throughout the general program of technological education.

We believe that great benefit would result to industry, to the engineering profession, and to engineering education if the condition here referred to could be clarified, and if the aims and purposes of programs at the several levels—secondary schools, vocational schools, technical institutes, and undergraduate and graduate engineering schools—could be more clearly understood and defined than they are at present.

One step that appears to be of primary and immediate importance in this connection, especially because of the impending complications of the postwar years, is the provision of means of formal recognition for institutions offering programs of the technical-institute type and for their graduates. At present, neither industries, generally speaking, nor the national engineering societies, nor engineering registration boards, nor federal civil service grant any credit for the educational preparation of graduates of sound institutions operating in this field. Lack of such recognition—or accreditation—caused the provisions of the engineering defense-training appropriations to limit the offering of courses to degree-conferring colleges at the very time when institutions offering sound programs of technical-institute type ought to have been rendering service of great value to the war effort. This anomalous situation should not have existed and it should not recur.

We believe that industry and the engineering profession as well as the schools and colleges should give united support to measures of recognition of sound technical-institute programs and of certification of their graduates for a considerable range of technical pursuits. These measures should be similar in general nature, but appropriately different in details and possibly in operation, to those now conducted by Engineers' Council for Professional Development as to engineering colleges, and by state boards of engineering examiners as to individuals. We believe that such measures of recognition and certification would ultimately bring genuine benefit to the colleges of engineering as well as to the technical institutes and their graduates.

PART I CONCLUSION

War experiences have altered temporarily the norms of engineering education but have not indicated the desirability of radical changes. With the cessation of hostilities wartime expedients should give place as rapidly as practicable to normal functions and the healthy processes of evolution should be resumed. The directives of the 1940 Report on Aims and Scope of Engineering Curricula remain essentially valid, within their limits. Events have shown one major extension to be needed, namely, a more positive indoctrination in civic and professional responsibilities. It has also become increasingly clear that secondary education needs to be strengthened, especially in mathematics and science, as a means of preparing for collegiate engineering education and means to this end must be sought vigorously.

The bounds of the undergraduate period are set at one limit by secondary education and at the other by certain goals of mastery distinctive to engineering and essential to its professional func-

tions. These goals include mastery of fundamental scientific principles, engineering modes of thought, basic knowledge in some major branch of engineering, elementary competence in the art of engineering application, some understanding of cost relations, skill in the use of English, insights into social relations and processes, and concepts essential to worthy personal and professional life. The goals of advanced knowledge and specialized technique belong properly to graduate and post-college training. The major paths along which progress is to be sought in the undergraduate period include the choice of essential matters and the elimination of nonessential matters of instruction, the grouping of the chosen materials into coherent major sequences, the inculcation of effective habits and standards, skillful combination of teaching methods, the development of creative as well as analytical abilities, and the evaluation of the attainment of the larger goals as well as the details of learning.

Matters relating to administration and management which conform to engineering modes of analysis and procedure have a valid place in engineering education. Trends in industry also make opportune increased attention to the production of industrial materials and of consumer goods, and to the recruitment of the production personnel as distinct from research and planning personnel.

The restoration of graduate work and its extension in scope to include all areas of advanced specialization should be immediate postwar goals. Instruction and research should be developed as complementary and co-ordinate functions.

The committee believes that both industry and the engineering profession would benefit from a clearer understanding of the relative functions of technical institutes of intermediate type and engineering colleges, and from the larger development and strengthening of the former. This can be aided by—in fact can scarcely be accomplished without—the establishment of appropriate measures for the recognition of technical institutes by the engineering profession and the acceptance of their graduates by industry and government for a wider range of subprofessional technical occupations.

It is the hope of this committee that one of the chief results of this report will be the stimulation of educational experimentation among engineering colleges and the presentation of papers before regional and national meetings of this society on specific measures for accomplishing the purposes indicated herein. The immediate postwar period, when readjustments must be made in any case, would seem to be an opportune time for the trial of new methods and for the dissemination of information about them.

II MATTERS OF IMMEDIATE CONCERN

As has been stated earlier in this report, all education is at present in a state of flux. It is appropriate, therefore, to re-evaluate engineering education in the light of the new conditions that surround it. Opportunity is afforded to compare conventional educational programs with those of unusual pattern and great variety that the colleges are now conducting. In the same institution, under the same administrative control, and with the same faculty, there are now in progress, in many cases, regular engineering curricula for civilian students, the Army Specialized Training Program, the Navy College Training Program, other special courses for the military services, special full-time training programs conducted for war industries, and the courses of the Engineering, Science, and Management War Training Program. Out of this complex situation certain facts emerge and certain lessons may be learned. It is clear also that difficult problems lie ahead for which solutions must be found as soon as possible; and it is also clear that the solution of some problems must await removal of uncertainties due to war and actions of government.

Secondary-School Preparation for Engineering. Evidence is appearing to support the belief previously held based upon only partial proof, that secondary-school education unless specially planned is generally inadequate as preparation for collegiate engineering education. By means of the qualification tests of the Army and Navy college-training programs students possessing high scholastic aptitude have been selected; yet poor preparation, especially in mathematics and science, has caused the failure of large numbers of the students of top-ranking ability among high-school graduates. The results of these tests are also indicating wide variation in the quality of secondary-school preparation in various parts of the country. More complete study of the results of a series of these nation-wide examinations taken in each case by several hundred thousand candidates will provide the basis on which high-school administrators and teachers and members of engineering-college faculties should be able to co-ordinate their programs and close the gap that has too long existed between secondary and collegiate education.

We suggest, therefore, that the appropriate agency of the society present the data derived from the Army and Navy qualification tests to state departments of public instruction, to associations of high-school principals and public-school superintendents, and to teacher and parent-teacher organizations with all the emphasis that the importance and accuracy of this material warrant.

Selectivity in Admission of Students. At the same time, evidence of the war-training programs indicates plainly that the practice of indiscriminate admission of students wherever it obtains should be abandoned in favor of one of greater selectivity. More valid measures of scholastic attainment and aptitude are now being developed. They should be used as soon as they are ready. This society, Engineers' Council for Professional Development, and the Carnegie Foundation for the Advancement of Teaching are actively engaged in this undertaking. This movement should be supported vigorously by the engineering profession as well as by the engineering schools themselves.

Junior College Preparation for Engineering. Growth in numbers of students transferring from junior colleges to engineering colleges points to the desirability of closer co-ordination of the programs of the two than now exists. Experience indicates that in some instances the present lack of co-ordination is due to lack of knowledge of the requirements of engineering curricula. It would seem advisable for Engineers' Council for Professional Development and this society to co-operate more effectively with junior colleges, looking to improvement in the preparation of candidates for admission in advanced standing, in an undertaking similar to that now in progress to insure the admission of better-qualified entrants from the secondary schools.

Scholastic Ability Vs. Financial Resources. One feature of the Army and Navy programs should be widely adopted in times of peace if means of doing so can be found, namely, the admission of students on the basis of mental capacity (a national resource that should not be wasted), scholastic preparation, and physical fitness without regard to the immediate ability of the student and his family to meet the expenses of a college education. This democratic process is one of the best things that has come out of the war situation and it should be continued. Means of doing so are not as readily discerned as is the desirability of the end sought. We would suggest the adoption of one principle in this connection, namely, that the student, who is the one most directly benefited, should share in the expense of his own education. Since in many instances he will not be able to earn all of these expenses, it would be desirable to establish a system of loans, in addition to present loans financed by the institutions, with local, state, or federal government supplying the capital, to be repaid from the increased earning power resulting from higher education.

If means can be found to institute this procedure, we believe

it should be utilized to insure the admission of better-qualified students, not as a means of inflating college enrollments.

Physical Conditioning of Students. We have been impressed with the results of more adequate physical conditioning of trainees provided in the Army and Navy programs. This points to the desirability of a re-examination of collegiate physical-training programs in times of peace.

Intensive Programs. It is possible that the retention in the postwar period of intensive programs of engineering study directed toward specific technical objectives, such as those of the E.S.M.W.T. programs, may be advocated by some as a continuing responsibility of professional schools of engineering. While fully supporting the offering of such programs under the exigencies of war, we believe that it would be unwise to continue many of them on the campus as the normal programs of engineering colleges in times of peace. Such intensive courses of specific aim as should have a permanent place in technological education belong, we believe, in the technical-institute field as referred to previously in this report.

Education of Veterans and War-Industry Workers. The flow of returning veterans to the engineering schools has begun. It is probable that federal legislation will provide for the support of the better-qualified of these veterans through a sufficient period to complete their engineering education. For purposes of readmission procedures, returning veterans may be classified in four groups:

1 Those who will resume their curriculum at the point of interruption without the need of any special process of adjustment, and those who will enter regularly as freshmen.

2 High-school graduates who have not attended college but have pursued part or all of a war-training program at college level, such as the Army Specialized Training Program.

3 Former engineering-college students who have pursued all or a part of a military training program and desire to re-enter in higher standing than at the point where their civilian program was interrupted.

4 Former college or high-school students who wish to complete their education by pursuing an abbreviated program either on a full-time or a part-time basis in order to become financially independent as quickly as possible.

The first group will present no problem. For groups 2 and 3 the problem will be essentially the same, that is, of supplementing the schedule of courses of the military training program so as to get the students in step in regular engineering curricula as quickly as possible. Many of these cases will require individual treatment. It may be necessary to admit veterans at times other than the beginning of a semester or term. An "adjustment term" has been suggested as an expedient to meet this difficulty. One such plan, already adopted, is to arrange special courses each to be pursued intensively for a four-week period. This will permit the returning veteran to re-enter college at the beginning of any four-week period and to resume regular work at the beginning of the next following semester with some of his irregularities adjusted. Such a plan, obviously, can be conducted only in institutions having faculty groups large enough to absorb the additional teaching load. The chief difficulty in the adjustment process will probably be to complete adequate foundations in mathematics and science for the pursuit of professional engineering courses, as well as to round out incomplete work in English and the humanities. While the colleges will desire to deal with these students liberally by reason of the sacrifice they have made for the sake of the national safety, they will not wish to jeopardize the interests of the students themselves by providing programs of subnormal quality for them. It would seem wise, therefore, to follow the policy of providing programs that will meet the general educational objectives of a standard undergraduate curriculum without insisting upon minute details of course-to-course equivalence.

For the transitional period it may be desirable to continue year-round calendars in order to complete the process of readjustment quickly. It may also be advisable in some instances to provide separate class sections for veterans whose education has been interrupted for long periods instead of placing them in the same classes with less mature students who have progressed with less interruption.

Returning veterans and displaced war-industry workers who desire to resume normal civilian pursuits more quickly than is possible in regular programs may desire to pursue short intensive courses having specific vocational aims either on a full-time or a part-time basis. Many engineering colleges that have participated in the war-training programs of the United States Office of Education (E.S.M.W.T.) may feel obligated to continue work of this type in the early postwar years. Those which have extension divisions or evening sessions can do so with only the difficulties incident to a peak load such as has been carried during the war period. Other institutions may find it necessary to ration their facilities under the anticipated combination of a resumption of normal undergraduate and post-graduate work, programs for returning veterans, and the offering of courses of the E.S.M.W.T. type. No formula can be written as a guide to the solution of this difficulty.

Educational Guidance of Veterans. A period of time will elapse for members of the armed forces between the termination of the more active phases of military duty and actual demobilization. In some instances this period will be spent in recovery from physical or mental injuries. It may occur either before or after the armistice. Under whatever conditions or at whatever time this interval will be spent, provision should be made to assist and advise veterans in making their individual plans for resumption of interrupted educational programs. This society and individual engineering colleges should offer co-operation to whatever authorized agency is charged with the responsibility for guidance and assistance.

When the period awaiting demobilization is long, refresher courses may be offered by the armed forces to facilitate the transition from military to civilian life, to utilize profitably the mental energy of veterans in preparation for resumption of engineering study, and to maintain morale. Engineering educators should keep themselves informed of such measures as these in order to co-ordinate their own programs of instruction with them and thus better to aid veterans to adjust themselves to renewed engineering study and to minimize the lost period of productive civilian pursuits.

Universal Military Service. Legislation providing for universal military service in the postwar years is now under consideration. Whatever the provisions of such legislation may be it seems clear that if adopted they will have important effects on higher-educational programs. If young men are required to devote a full year to uninterrupted military training as soon as they reach a designated age or when they graduate from high school, the effect will be to defer entry to college correspondingly. The possible disadvantage of discontinuity of schooling resulting from such a plan may be offset by increased maturity and better-disciplined attitude toward work and study. If military duty may be performed in several shorter periods of duty, such as three or four months during each of several successive years, the result may be strongly to influence the colleges to adopt a four-term or three-semester calendar. Furthermore, if military procedures are such that quotas of students are called up for duty in each three-month or four-month period, the effect may be to cause continuation of a year-round academic calendar. Obviously, either of these procedures would have important effects on the possibilities of vacation employment by students in industry.

If universal military service is operated on the plan of a full year of duty performed in one continuous period, the resulting deferment of admission to college may cause some students to desire to follow some form of accelerated program in order to graduate as quickly as possible.

Army and Navy R.O.T.C. programs may also be affected by

universal military service, but the details of legislation will have to be awaited before these effects will be known.

While it is possible at present only to conjecture about the foregoing contingencies, they must be kept in mind as possibilities in connection with postwar planning.

The Accelerated Program. If military conditions are such as to allow freedom of choice as to the type of calendar to be adopted after the war, there will doubtless be discussion of the desirability of continuing the present type of accelerated program. We believe that the following considerations will be recognized as outweighing the advantages of the accelerated program under normal circumstances:

1 Difference in maturity of graduates of the program of four calendar years as contrasted with those of the accelerated program of shorter duration.

2 The value of vacation periods spent in acquiring industrial experience as well as the maturing influences which result from contact with engineers and industrial workers in practice.[2]

3 The value to faculty members of periodic opportunities for industrial experience, for full-time research, for writing, or for other broadening pursuits as well as the mental stimulus that comes from periodic change of occupation.

Academic Credit for Military Programs. For recommendations relating to policies in this matter the reader is referred to the report[3] of the committee of the Society for the Promotion of Engineering Education on "Credits for In-Service Study."

More specific information concerning the educational work done under the auspices of the armed forces will be found in the handbook to be published by the American Council on Education.

Rehabilitation of Faculties. The effects of the war on engineering faculties may be epitomized as a growing need of rehabilitation. The longer the duration of the emergency, the more acute the cumulative situation becomes. The normal recruitment and development of able young teachers to fit them to fill important posts has been replaced by appointments based on expediency. This leads to the danger of permanent retention of the poorly qualified. Many of the ablest teachers in the younger and middle-aged groups have entered the armed services, war research, or highly paid industrial positions. Some of these will return with the asset of valuable experience acquired; others have been lost permanently, including those who will remain in our enlarged military establishments. Some who return to their college posts may find them less challenging than the positions they have occupied in the Army and Navy and war industries. These latter groups include many whose vigor and ability qualify them to become the future keymen in engineering faculties. Great care must be exercised to assist these men to readjust themselves to the conditions of academic work and to give them opportunities for the exercise of their enlarged abilities. Other keymen will have to be replaced. Faculty groups as a whole will need a period of rest and recuperation from the long grind of continuous work under heavy overload.

No more serious problem could confront the engineering schools than that of postwar faculty rehabilitation. No simple or quick process of solution can be discerned for it. We can merely state some aspects of the problem and sound the caution that the greatest possible care and patience should be exercised in attacking it so as to adhere to the high standards of faculty selection and upbuilding that the interests of engineering education require.

PART II CONCLUSION

Each of the matters discussed in the preceding paragraphs is of individual importance and will demand attention in the postwar years. In the aggregate they will have an important bearing on the course that engineering education will follow for many years. Two problems stand out as of great importance: (1) Devising more valid means than have been employed in the past for selecting and admitting students and insuring better preparation in secondary schools, and (2) building up faculties not only to the prewar level of effectiveness but well above that level. Engineering education can never advance beyond the qualifications of its students and teachers. Hence, the engineering profession, industry, and the public who have a vital interest in its welfare, should vigorously support every possible means of improving the quality of its personnel.

Of more immediate concern is the planning of appropriate educational programs for returning veterans in order to permit them to enter productive pursuits in the minimum time consistent with sound practice. This can and will be done. We would call attention especially in this connection to provision of postgraduate work, either full time or part time, for those who desire and can profit by it.

If, as present indications seem to suggest, there is to be a reaction away from the wartime accelerated academic calendar and if conditions of universal military service are such as to permit freedom of choice in relation to this matter, it may be necessary to meet the criticism of those who see serious waste in permitting valuable educational facilities to be operated for less than a full calendar year. We have referred previously to the values derived by students from the experience and the maturing influence of employment in industry. Engineering colleges might well establish systematic means of aiding students to secure employment that will afford the right sort of experience,[4] and of requiring such experience as a prerequisite to graduation. If educational programs are to be in regular operation for less than the full calendar year, it is equally important that vacations be used profitably by teachers. It seems appropriate, and even necessary, that they be expected to spend vacations in industrial employment, research, writing, or other pursuits that will keep them abreast of current developments in science and engineering or otherwise promote their professional advancement.

Finally, and of the utmost importance during postwar years will be the inevitable problems of financing higher education during a period of world-wide economic rehabilitation. One not inconsiderable aspect of this matter will be the necessity of restoring to normal efficiency laboratory facilities worn out or damaged by war usage. The war has caused a suspension of replacement of items of equipment that have become obsolete; others have undergone abnormal wear and deterioration; provision must be made to make good these deficiencies. In sum, a period of serious financial difficulty lies ahead.

Wide fluctuations in enrollment of engineering students are being experienced. These fluctuations occur not only in total numbers but in distribution by years and curricula. It is to be anticipated that this condition will continue into the postwar period. It is possible also that in the immediate postarmistice years there will be a considerable influx of new students at the same time that veterans are returning to complete their curricula. How long this condition will continue is a matter of conjecture, but it seems plain that the resulting problems will be severe in the internal administration of engineering colleges.

If at the same time there is to be a permanent increase in enrollment in science and engineering, and if colleges of engineering are to occupy a larger place and exercise a more general function than they do at present in the scheme of collegiate education in this country, it is not only appropriate but necessary to plan in advance for the facilities and staffs which these changes will require. And it is especially important that the educational problems that will accompany such an expansion of scope and function should be considered on broad lines in the interest not only of industry and the engineering profession but of the nation as a whole.

[2] The values of periods of industrial employment for undergraduate students as here stated are provided systematically for students of co-operative engineering curricula.

[3] Published in the *Journal of Engineering Education*, November, 1943.

[4] Certain colleges achieve this result through the co-operative plan.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Porous-Chromium-Plated Rings

COMMENT BY JOHN DICKSON[1]

The writer is particularly interested in the chromium plating of piston rings.[2] We know that, in general, the wear of the cylinder liner is localized near the top of the liner, and that only in the case of extreme dust-laden conditions does the cylinder liner show a tendency of wearing barrel-shaped. In any event, the wear of the liner is traceable to ring conditions, either at positions of low speed or maximum speed in the engine cycle. This localizing of the wear would seem to indicate that chromium plating of the piston ring would be the more economical way of obtaining similar good results.

The paper contains measurements made on a number of engines which may or may not substantiate the writer's previous remarks. The wear figures for the unplated cylinder liners show that the wear is greater for the smaller number of operating hours. Table 1 shows that at 409 hr the wear is 0.007 in., while for 743 hr, the wear is only 0.003 in. Plotting the results in wear per 1000 hr, engine A, B, E, and F give a smooth curve while engines C and D lie astride the curve. If the figures can be accepted at their face value and substantiated by other tests, engineers would extrapolate the curve to approximately 1000 hr of operation and expect that examination of an engine at this period would give no evidence of cylinder-liner wear. Perhaps the author will be able to offer an explanation.

COMMENT BY RALPH MILLER[3]

At the writer's plant, we had in operation a supercharged engine rated at 115 bmep, in which we found it impossible to maintain the piston rings. We wore out five or six sets, each set lasting only about 10 or 12 hr. Naturally, the liners were in pretty bad shape after that. Nevertheless, we secured a set of chromium-plated rings. The rings had been made with sharp corners, and, since we do not like sharp corners on piston rings, we rounded these off as well as we could by hand grinding. Then we installed them in the badly scuffed liners. Soon, smoke in the crankcase indicated bad piston rings. When removing the pistons we found that the rings instead of having taken a high polish were scuffed and showed signs of excessive heat. They were deeply scratched vertically, but still the chromium adhered to the rings. However, they were leaking badly, and the liners were not polished as they should be for that type of job. The test was a failure. We removed the rings and, due to the pressure of work, were unable to try new liners with chromium-plated rings as we should have done. Instead we oil-cooled the pistons and corrected the trouble.

Our next experience occurred in connection with a pipe-line job. In this case a series of 5-cylinder engines had for a period of a year and a half given repeated trouble with scuffing of piston rings. It was a rather unusual case because the mean effective pressures were low and the speed normal. Many remedies were tried, such as changing lubricating oils, etc., without any improvement. Finally, although we had had the experience mentioned on the supercharged engine, we decided again to try chromium-plated piston rings. These rings were installed in one of the 5-cylinder units on December 13, 1941. When the engine was taken down to install these rings, four out of five liners were badly scored and the rings were scuffed. We replaced some of the liners and installed chromium-plated rings on three pistons, Nos. 2, 4, and 5. Of these Nos. 2 and 5 were new liners, but No. 4 was the old liner which had been running a long time and had worn out a number of cast-iron rings. It was in bad shape. On May 19, 1942, the writer had the engine dismantled for inspection. It had then operated 3423 hr. Upon removing the pistons, we found the liners in which the chromium-plated rings had been running in very fine condition. No. 4 liner, which previously had been scored, had polished up beautifully to a mirror finish. The rings were likewise polished, and there was no measurable wear on the rings. The other two cylinders which had been equipped with new liners in December were also in very fine shape. They were highly polished and showed no wear. The remaining two cylinders with the cast-iron piston rings had again scuffed both rings and liners. The rings were badly worn. These results have been so encouraging that we shall undoubtedly use chromium-plated rings extensively in the future.

The author now indicated that, after we wear off 0.0015 to 0.002 in., we get down to hard chromium. On this particular job we only wore off a fraction of 0.001 in., and it was still running on the porous chromium. What happens when that is worn off and hard chromium comes to the surface? Does the same condition exist in chrome-plated liners? Do we have porous chromium on the surface 0.0015 in. deep; if so when that is worn off, perhaps in 10,000 hr, what happens? It is important to know the answer, because wear has not been eliminated altogether by the use of chromium.

COMMENT BY W. M. NICHOLS[4]

The author has not sufficiently covered the most important reasons for chromium-plating of either rings or liners, namely, the elimination of the dangers of scuffing.

The early history of the development of machines indicates the common usage of cast iron on cast iron as rubbing surfaces. With the introduction of babbitt metal, this practice was changed, until today, a great many varieties of dissimilar metals are in common usage on most highly developed machines. The one notable exception is piston rings against cast-iron cylinder walls. In other words our present internal-combustion machines largely still belong to the same classification as crude mechanisms of an earlier day.

It is extremely difficult if not impossible to find justification for the faith which we have in ordinary cast iron as a suitable piston-ring material. Where else can one find these similar materials operating at unit pressures of approximately 1000 psi or more at comparable velocities and with indifferent lubrication to say nothing about the burden imposed by the high operating temperatures?

If we agree that cast iron rubbing against a similar liner surface leaves much room for improvement, then we naturally ask ourselves this pertinent question: "Does ordinary cast iron have other outstanding properties which make its con-

[1] General Motors Corporation, Diesel Engine Division, Detroit, Mich.

[2] "Cylinder and Ring Life With Porous Chromium-Plated Rings," by T. C. Jarrett, MECHANICAL ENGINEERING, vol. 65, 1943, pp. 633–635.

[3] Chief Engineer, Worthington Pump and Machinery Corp., Buffalo, N. Y. Mem. A.S.M.E.

[4] Experimental Engineer, American Locomotive Company, Auburn, N. Y. Mem. A.S.M.E.

tinued future use essential?" Here again there is much room for skepticism.

There seems to be no question about the desirability of having a ring which will conform to the irregular shape of a liner during operation. This requirement necessitates a ring having a rather small radial depth. However, other factors such as desirable tension, ring flutter, etc. make this impossible when using iron having an elastic modulus of around 13,000,000.

Much has been said about ring flutter, and to overcome this condition it has been customary to make rings with a so-called "plus circularity" which seemed to be of some benefit. It is interesting to note that this plus circularity did not change the natural frequency of vibration of the ring, but merely introduced a condition whereby a greater stimulating force would be necessary to make the ring leave the liner. In principle it is the same as trying to stop valve-spring surge by increasing the initial loading, which we all know cannot be done.

If we now adopt a material with an elastic modulus approaching that of steel, we at once change the natural frequency, we can get better conformability, and we can use much more fragile rings without the danger of breakage, all of which seem at present to be desirable.

COMMENT BY T. G. COYLE[5]

While porous chromium certainly has virtues to recommend it, and we do generally use it on piston rings, there are some important exceptions where, on certain types of piston rings for aircraft engines, a dense chromium plate is used. One exception is on certain taper-face rings where it is considered that the porous chromium wears too rapidly to retain for a sufficient length of time the advantage of the taper-face design. On that application, at least, a dense chromium plate has been found advantageous.

As to the specifications, taking the points in the order listed, the following comments from our experience are offered:

Honing prior to plating has not been found necessary, and we do not practice it. We place no special importance on high surface finish preparatory to plating.

The plate-thickness values are good and to be recommended.

The depth of pores also represents a good value, but if a specification is to be drawn, we believe some allowance should be made for exceptions such as noted where there is no porosity (in the sense used here) whatever. This nonporous plate is considered necessary in some quarters, and that it may be satisfactory is in part borne out by the figures in the paper, where, after the porosity is worn through, we have essentially a hard chromium plate which continues to give good service.

We would avoid a profilometer specification, since it might be misleading. In place of that we would substitute some specification based on a microscopic examination, for comparison with standardized photomicrographs and covering both degree and depth of porosity.

As to specifying that the porosity should be produced by reverse-current treatment, it should be pointed out that porosity can be obtained by other means. In view of this, the propriety of introducing methods limitations is questioned.

On stress relief (if that is considered necessary), we doubt that much is obtained by simple immersion in boiling water for as short a time as 1 hr. If a stress-relief treatment is considered desirable, we would recommend heating at a higher temperature and a longer time, for example, 300 to 350 F, maybe 500 F, for 2 to 3 or 4 hours.

A very serious omission in the specification is any reference to adherence. An adherence test certainly should be specified. Fortunately, a simple test has been found which is very effective. It consists merely of placing the piston ring on an anvil and hammering the sides and noting how the plate adheres and the character of the fracture of the chromium plate. We have found it to be a good and practical test for the shop and laboratory.

The writer would raise the question whether such a specification should state something as to fatigue. Similarly, and possibly more important, if it is to be a complete specification, should not the type of porosity be specified? It is known that different types of porosity are obtainable by varying operating conditions and have different operating characteristics.

To sum up these comments on specifications, we think the specification could be brought down to a few essentials, namely, plate thickness, depth of porosity (and possibly type), and certainly adherence.

In the opening remarks of the paper, there were some statements about "dense" or "hard" chromium plating and how it is done. It is true that higher current densities are used in "hard" plating, as compared with "decorative" plating, but this is primarily to get higher plating speeds, not higher hardness. Just as high a hardness can be obtained at lower current densities, provided the operating conditions of bath composition, temperature, and current density are co-ordinated.

The author gives values on the normal thicknesses used in chromium plating which the writer believes should be corrected. On decorative plating there appears to be an error, because the normal thicknesses in decorative plating, instead of being 0.0002 in. to 0.0005 in. are normally 0.00001 to 0.00002 in. That is the usual thickness used for decorative work and in a few exceptional cases, the chromium plate is as heavy as 0.0002 in. Similarly, with ordinary "dense" or "hard" plating, the thicknesses are usually quite different from those given in this paper, and generally range from 0.001 to 0.003 in. When they are heavier, it is generally a matter of salvage; there are plates as heavy as the salvage job requires, maybe up to 0.100 in.; but a plate of 0.003 or 0.004 or 0.005 in. will generally perform as well as anything heavier than that. In the other direction, it is not at all uncommon in hard plating to plate much less than 0.001 in. Here we have the very important application to tools which the author mentions. The usual thickness in cutting tools is a fraction of a ten-thousandth, perhaps 0.00005, 0.00006, or 0.00007 in., up to possibly 0.0002 in. In fact, the thing to avoid here is getting too heavy a plate, because in cutting tools a heavy deposit generally is detrimental.

The author mentions that it is not necessary to lap rings. The writer believes the necessity for lapping depends upon the importance placed upon having rings light-tight, and the effect this has on oil control in the run-in of the engine.

AUTHOR'S CLOSURE

Mr. Dickson brought out an interesting point. (1) It was not a typographical error. (2) It was a matter of chance, and the figures were picked out of approximately 165 engines. (3) It is important, as we have an engine with 658 hr operating time in Table 1 showing 0.004 in. wear, and then we also have other engines with 658 hr operating time in the same territory showing a wear of 0.010 in. This means that the slope of the curve instead of going down gradually, as shown in the paper, would deviate sharply to one side and then come back to the original slope. In a similar fashion, we have other engines operating as high as 1492, 1373, and 1175 hr which show as much as 0.014 to 0.020 in. wear.

On the other hand, Mr. Dickson brought out an important fact, namely, that there may be a possible physical change in the cylinder itself. When we examine engines in the future, observations will be made to see if something of this nature has taken place.

In regard to Mr. Miller's question, the author is familiar with the engine referred to and, at this time, cannot offer the exact answer, except that some engines need special consideration, and it may be that this engine is one of them.

Regarding his question as to what happens when the porosity wears off, it can be stated that the engine performance does not change. Porosity itself, present only on the cylinder contacting surface and, having a depth of 0.0015 in.,

[5] United Chromium, Inc., Detroit, Mich.

permits the ring to mate itself to a bearing with a cylinder wall, and also conditions the barrel itself. The porosity completely disappears in approximately 50 to 60 hr. From that point on the ring possesses a hard chromium surface. Porous-chromium-plated rings operate the same way in all engines. The porous-chromium-plated rings have a decided advantage of being able to seat quickly, particularly where the barrel is out-of-round.

A test was conducted on rings which had been run 446 hr. These rings, possessing no porosity, were installed in a newly honed barrel and operated for 5½ hr. At the end of this period, the oil consumption was normal and the rings themselves were fully seated. On the other hand, if you put newly plated rings which were not porous and not lapped in the same type of barrel, the rings and the barrel would be badly scratched. The reason, we believe, that the rings with 446 hr service did not scratch was due to the rings' being lapped into the barrel under actual operating conditions. Porous-chromium-plated rings really proved themselves in the days of ring feathering. At one time, one particular engine builder found it impossible to get the engines off the test block without the rings' being feathered and scuffed. Porous-chromium-plated rings were installed in the same barrel and in no instance did the engine fail to come off the block with rings and barrels satisfactory.

Mr. Coyle has brought out some important points. His first reference is to tapered OD chrome-plated rings which are used by some aircraft-engine builders. This particular aircraft-engine builder today is using porous-chromium-plated rings and, in one test after the rings had gone 250 hr under severe operating conditions, such as take-off and diving power, only one half of the taper of the porous-chromium-plated ring was worn off.

Of all the porous-chromium-plated rings we make, very few of the rings are light-tight. The reason for this is quite obvious, as the porous-chromium plate itself prohibits the ring from coming in tight contact with the light gage. If this same ring is put into a cylinder, the small pinnacles of the porous chromium plate will lap themselves down and produce a light-tight ring in a very short period of time. This is extremely important for green barrels. In a test which was recently completed, using a non-lapped tapered OD chromium-plated ring, the results showed this type of chromium ring worked satisfactorily and was superior to the lapped hard-chromium rings.

We had the pleasure of seeing one engine builder who set up several engines with porous-chromium and hard-chromium rings for test and, for the first time, we observed feathered chromium-plated rings. This ring when installed in an engine was of the hard-chromium type and not porous. This substantiated our experience of former days, which proved that we could not use a ring with low porosity.

The specifications given in the paper were drawn up after 2 years of experience and after producing some 2,000,000 plated rings. The hardness of the chrome plate, as mentioned, is essential.

As to the depth of porosity, it is correct, and the profilometer is essential, as we do tie up the profilometer readings with the microscopic readings. They must go hand in hand to interpret the specifications correctly.

In regard to the heat-treatment of the chrome-plated rings, we have found from our experience, test, and research, that it is unwise to heat-treat the chromium-plated rings. Heat-treatment other than boiling water softens the chromium plate and reduces the ring life. In our process of manufacture, all chrome-plated rings are allowed to remain in boiling water 1 hr after they are plated and to date we have found no traces of hydrogen embrittlement.

Mr. Coyle is correct when he states that tools, such as reamers, etc., are generally plated, using 0.001 to 0.003 in. of chromium, but in our shop we found a heavier chromium plate to be much better.

TRACY C. JARRETT.[6]

[6] Chief Metallurgist, American Hammered Piston Ring Division, Koppers Company, Baltimore, Md.

Glued-Laminated Lumber Construction

COMMENT BY M. B. WELLS[7]

After studying the illustrations accompanying this paper,[8] the writer feels that the use of bolts is preferable in laminated arches. Such arches, especially when used for roof supports, may have moments that give tension on the inside of the curves causing the laminations on that side to tend to straighten and give direct tension perpendicular to the glue lines. A reasonable number of bolts in such locations is a desirable precaution. They may be put in after the arches are taken from the jigs or molds.

In looking over some of the rapidly built laminated construction in the Chicago area, we have found some open glue joints. In wood we have a material that tends to warp, bend, and twist when seasoning, some species being worse than others. These facts should be kept in mind by designers and fabricators. Both should co-operate in an educational program for foremen and other workers, emphasizing the importance of following instructions regarding moisture content, preparation of surfaces to be joined, and the time, temperature, and pressure requirements for handling adhesives, with special reference to the synthetic resins.

As has been stated, we are in the early stages of the use of laminated wood. We should not allow it to come into disrepute because of a lack of caution.

AUTHOR'S CLOSURE

The comments by Mr. Wells calling attention to the importance of workmen adhering strictly to the proper procedures and techniques of manufacture are well taken. This is essential for high-quality, glued, lumber product for structural uses.

However, the author is not in accord with the comment that " . . . the use of bolts is preferable in laminated arches." If the proper glue is used and the proper techniques are employed for the particular service conditions involved, imperfections of the type mentioned by Mr. Wells will not be of a magnitude which appreciably affect the structural integrity of of the member and no such reinforcement is needed.

Further, the bolts and glue cannot be assumed to act in structural unison because the glue begins to take load with little or no deformation, whereas considerable deformation must take place before the bolts carry an appreciable amount of load. Consequently, the bolts do not serve a useful structural purpose until after the glue line has failed and then only the bolts are effective. Hence, the member should be designed for fastening of laminations by either glue or bolts but not on the basis of both acting together. Also when bolts are used, the strength of the glued member is reduced by the load capacity of the portion of the cross section removed in boring the bolt hole.

The design should be such that the maximum stress in cross-grain tension induced by change of curvature resulting from load or other causes is kept within the allowable working stress. Ordinarily this is not a difficult problem in design. Although the author has not made such studies, he has been informed by capable engineers who have, that for the arch curvatures, sections, and loadings commonly used, the induced stress in cross-grain tension seldom, if ever, exceeds one fourth to one third of the permissible working stress.

FRANK J. HANRAHAN.[9]

[7] Aetna Plywood and Veneer, Chicago, Ill.

[8] "Glued-Laminated Lumber Construction," by F. J. Hanrahan, MECHANICAL ENGINEERING, December, 1943, pp. 905–913.

[9] Structural Engineer, National Lumber Manufacturers Association, Washington, D. C.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code may communicate with the Committee Secretary, 29 West 39th St., New York 18, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of the Committee to all the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following is a record of the interpretations of this Committee formulated at the meeting of March 17, 1944, and approved by the A.S.M.E. Council on April 20, 1944.

CASE No. 940 (*Reopened*)

(*Special Ruling*)

Inquiry: Is it permissible to use flat plate materials complying with A.S.T.M. Specifications A 7, A 10, or A 78 as manhole covers for unfired pressure vessels?

Reply: It is the opinion of the Committee that manhole covers formed of flat plate, on which no strength welding is applied, may be made of the above materials provided the operating temperature does not exceed 650 F.

CASE No. 1007

(*Interpretation of Pars. P-198 and U-39*)

Inquiry: Pars. P-198 and U-39 and the accompanying Figs. P-21 and U-4 cover end closures of several designs for pressure vessels. Will a flat plate with beveled edges over which the cylindrical shell is crimped, as shown in Fig. 41, meet the intent of the Code?

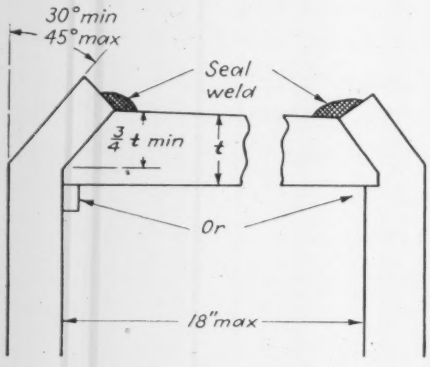


FIG. 41 ATTACHMENT OF A FLAT HEAD TO A CYLINDER

Reply: It is the opinion of the Committee that the form of construction outlined will meet the intent of the Code provided:

(1) The inside diameter of the shell or pipe does not exceed 18 in.;

(2) The ratio t_s/d is not less than the ratio P/S, nor less than 0.05;

(3) The angle of the bevel is not less than 30 deg nor more than 45 deg;

(4) The depth of the bevel is at least three fourths the thickness of the plate;

(5) The crimping is done while the entire circumference of the cylinder is at a temperature of not less than 1300 F;

(6) The constant used in the formula in Pars. P-198(*a*) and U-39(*a*) for calculating the thickness of the flat plate is not less than 0.50.

Proposed Revisions and Addenda to Boiler Construction Code

IT IS the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revisions of the rules and its codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the code, to be included later in the proper place.

The following proposed revisions have been approved for publication as proposed addenda to the code. They are published below with the corresponding paragraph number to identify their location in the various sections of the code and are submitted for criticism and approval from anyone interested therein.

It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York 18, N. Y., in order that they may be presented to the Committee for consideration.

PARS. P-102(*b*)(12*b*), U-68(*b*)(12*b*), L-102(*b*)(2*b*): Revise to read:

(*b*) Welds in which the radiographs show any type of crack OR ZONES OF INCOMPLETE PENETRATION shall be unacceptable.

PAR. P-112(*c*). Add the following:

For the attachment of nozzles to boiler drums or headers see Par. P-268(*o*).

PAR. P-198(*a*), U-39(*a*). Add the following:

$C = 0.50$ for beveled plates having a diameter, d, not exceeding 18 in., inserted into shells, pipes, or headers, the ends of which are crimped over the bevel with the limitations shown in Fig. P-21(*n*) (U-39*n*). The crimping shall be done when the entire circumference of the cylinder is uniformly heated to a temperature of at least 1300 F. For this construction the ratio ts/d shall be not less than the ratio P/S nor less than 0.05.

PAR P-268(*o*). Add the following:

When nozzles or couplings are attached to drums, shells, or headers of boilers as shown in Fig. P-36(*b*) and (*d*) and are welded from one side only, backing strips must be used unless the inside of the joint can be visually inspected so that the inspector may satisfy himself that complete penetration, as required by Pars. P-101 and P-112(*c*), is obtained.

PAR. P-317(*a*). Revise to read:

(*a*) The feed pipe shall be provided with a check valve near the boiler and a valve or cock (see Par. P-309) between the check valves and the boiler. Wherever globe valves are used on feed piping the inlet shall be under the disk of the valve. IT IS RECOMMENDED that when two or more boilers are fed from a common source, there shall [also] be a globe or regulating valve (except gate valve) on the branch to each boiler between the check valve and the source of supply.

TABLES P-7 AND U-2. Add allowable stresses of 1400 and 900 psi at 1150 and 1200 F, respectively for the following materials:

Specifications SA-213 Grade T13, SA-157 Grade C5B, SA-158 Grades P5a and P5c, SA-213 Grade T5, SA-182 Grade F5, SA-157 Grade C5A, SA-158 Grades P3a, P3b, and P11, SA-213 Grades T3, T11, T12, T14, and T16, SA-182 Grade F3.

PARS. A-19 AND A-20. Replace the proposed revisions published in March, 1944, MECHANICAL ENGINEERING by the following:

Par. A-19(*a*). Change first line to read: "Fire-actuated fusible plugs, if used, EXCEPT AS PROVIDED IN PAR. A-20(*i*), shall be filled with time of."

Par. A-20. Add the following:

(*i*) Fusible metal, other than tin as specified in Par. A-19(*a*), for use under temperatures exceeding 450 F, may be used and the casing may be made of other material and shape than specified in Par. A-20(*b*), (*c*), and (*d*) if the metal and the casing are approved by the administrative authority, but such plugs shall not be marked as "A.S.M.E. Std."

PAR. U-71(*a*). There are several typographical errors in this paragraph. Users of

this Code are therefore requested to correct their copy to read as follows:

(*a*) Ferrous materials used in the fabrication of any fusion-welded drum, shell, or parts, covered by this Code, shall conform to Specifications S-4, SA-7 (bar stock only), SA-27, SA-30, SA-31, SA-53, SA-70, SA-72, SA-83, SA-84, SA-89, SA-105, SA-106, SA-129, SA-135, SA-157, SA-158, SA-178, SA-181, SA-182, SA-192, SA-201, SA-202 Grade A, SA-203, SA-204, SA-206, SA-209, SA-210, SA-212, SA-213, SA-216, SA-217, SA-225, SA-240*, SA-249* Grades T8, T18, T19, and T20, and SA-250. The carbon content in all such materials shall not exceed 0.35 per cent.

PAR. U-78(*g*). Insert the following as the seventh section:

The segments or plugs after removal shall be properly stamped or tagged for identification and, after etching, kept in proper containers, with a record of their place of removal as well as of the welding operator who performed the welding. A record shall be made by the inspector of all specimens with their identification marks on a developed shell-plate diagram.

After the acceptance of the vessel, the specimens may be retained by the purchaser, if he so desires. Otherwise they may be discarded.

PAR. U-78(*g*). Replace the present seventh section by the following:

Holes in welded joints left by the removal of trepanned plug specimens may be closed by any method approved by the authorized inspector. Some suggested methods for closing round plug openings by welding are as follows:

(1) Insert and weld in special plugs of which some acceptable types are shown in Fig. U-19. Type (*a*) is adapted to welding from both sides and should be used wherever that method is practicable, and types (*b*) or (*c*) when access is possible only from one side. The diameter of the filler plug shall be such as to make a snug fit in the hole to be filled. Each layer of weld metal as deposited shall be thoroughly peened to reduce residual stresses. The 1/4-in. hole in the center of the plugs shown in Fig. U-19 may afterwards be closed by any reasonable method. Plain plugs without a hole may be used.

(2) For joints where the thickness of the thinner plate at the joint is not greater than one third of the diameter of the hole, place a backing plate on the inside of the tank shell over the opening and fill the hole completely with weld metal applied from the outside of the shell. Rebuild fillet welds where cut.

(3) For joints where the thickness of the thinner plate at the joint is not less than one third, nor greater than two thirds the diameter of the hole, fill the hole completely with weld metal applied from both sides of the tank shell. Rebuild fillet welds where cut.

(4) For butt joints where the thickness of the thinner plate at the joint does not exceed 7/8 in., chip a groove on one side of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the bottom of the hole, and the length of the groove on each side of the opening is to have a slope of approximately 1 to 3. Use a backing plate on the side opposite which the chipping is done or a thin disk (not over 1/8 in. thick) at the bottom of the hole and fill the groove and the hole with weld metal.

(5) For butt joints, and for plates of any thickness, chip a groove on both sides of the plate each way along the seam from the hole. The groove at the opening shall have sufficient width to provide a taper to the middle of the plate, and the length of the groove on each side of the opening is to have a slope of approximately 1 to 3. Place a thin disk (not over 1/8 in. thick) in the hole at the middle of the plate and fill the grooves and the hole on both sides with weld metal.

The following is a suggested method for closing openings cut with a spherical saw: For butt-welded joints place a backing plate, where necessary, on the inside of the vessel shell over the opening. For lap-welded joints, a part of the parent plate remaining opposite the removed weld will usually serve as a backing plate. Fill the opening completely with the weld metal. Rebuild fillet welds where cut.

PAR. H-34. Add the following:

Lugs, hangers, or brackets made of materials in accordance with the Code requirements may be attached by fusion welding provided they are attached by fillet welds along the entire periphery or contact edges and the throat dimension of the attachment weld is at least .7 times the shell thickness. The stresses computed by dividing the total load on the lug, hanger or bracket by the minimum cross-sectional area of the weld shall not exceed 2800 psi.

SPECIFICATION SA-27. To be dropped. References in Code to this specification to be deleted.

SPECIFICATION SA-176. To be dropped in view of revision of Specification SA-240.

SPECIFICATION SA-233. Par. 6 of this specification will be revised to make it identical with A.S.T.M. 233-43T.

SPECIFICATION SA-240. Table 1 of this specification will be revised to read:

SPECIFICATION SB-126. Table 1 of this specification will be revised to make it identical with A.S.T.M. B126-43T.

SPECIFICATION SB-184. This will be a new specification, identical with A.S.T.M. B184 for Aluminum and Aluminum-Alloy Metal Arc-Welding Electrodes.

SPECIFICATIONS SA-263, SA-264, SA-265. These will be new specifications identical with the following A.S.T.M. specifications:

A 263–43T Specifications for Corrosion-Resisting Chromium Steel Clad Plate, Sheet, and Strip

A 264–43T Specifications for Corrosion-Resisting Chromium-Nickel Steel Clad Plate, Sheet, and Strip

A 265–43T Specifications for Nickel and Nickel-Base Alloy Clad Steel Plate.

RULES FOR LAYER OR BANDED PRESSURE VESSELS

These rules cover welded pressure vessels in which the cylindrical portion is made up of an inner layer and five or more contacting layers, which are welded in place. The innermost cylindrical layer is defined as the inner shell. Except as modified by the rules of this section all of the rules of Section VIII shall apply, and vessels built in accordance with these rules and the applicable parts of Section VIII may be used for any purpose.

UL-1(*a*). The inner shell, heads, and openings may be made of a suitable alloy to resist corrosion, erosion, or abrasion in which case the corrosion allowance shall be based upon the character of the alloy or alloys used. The minimum thickness of an inner shell shall be 1/4 in.

(*b*) The inner shell, heads, and openings may be lined with a suitable alloy of sufficient thickness to resist corrosion, erosion, or abrasion and no further thickening of the vessel wall need be provided for corrosion resistance. The lining alloy may be integrally bonded, or spot or plug welded to the inner shell. The minimum thickness of such a liner shall be 1/16 in.

UL-2(*a*). In addition to the materials provided for in Pars. U-13 and U-71, the following materials may be used for the construction of inner shells only, provided the carbon content in all materials to be welded does not exceed 0.35 per cent:

A.S.T.M. A167–42. Specifications for Corro-

TABLE 1 CHEMICAL REQUIREMENTS

Grade	Type number	Carbon,[a] max, per cent	Manganese, max, per cent	Phosphorus, max, per cent
A	410 modified	0.12	0.60	0.030
B	.....	0.12	1.00	0.030
D	430 modified	0.12	1.00	0.030
S	304 modified	0.08	2.50	0.035
M[b]	316 modified	0.08	2.50	0.035
C[c]	347 modified	0.08	2.50	0.035
T[d]	321 modified	0.08	2.50	0.035

Grade	Type number	Sulphur, max, per cent	Silicon, max, per cent	Chromium, per cent	Nickel, per cent
A	410 modified	0.030	0.75	12.00 to 14.00	0.60 max
B	.....	0.030	0.75	14.00 to 16.00	0.60 max
D	430 modified	0.030	0.75	16.00 to 18.00	0.60 max
S	304 modified	0.030	0.85	18.00 min	8.00 min
M[b]	316 modified	0.030	0.85	17.00 min	10.00 min
C[c]	347 modified	0.030	0.85	17.00 min	9.50 min
T[d]	321 modified	0.030	0.85	17.00 min	9.00 min

[a] The carbon analysis shall be reported to the nearest hundredth of one per cent.

[b] Grade M shall have a minimum molybdenum content of 2.0 per cent.

[c] Grade C shall have a columbium content of not less than ten times the carbon content and not more than 1 per cent.

[d] Grade T shall have a titanium content of not less than five times the carbon content and not more than 0.60 per cent.

* Materials complying with these specifications to be used only under the conditions set forth in Case No. 897.

sion-Resisting Chromium-Nickel Steel, Plate–Sheet, and Strip (Plate only).

A.S.T.M. A177-39. Specifications for High-Strength Corrosion-Resisting Chromium-Nickel Steel, Sheet and Strip.

SA-176. Specifications for Corrosion-Resisting Chromium Steel Plate, Sheet, and Strip (Plate only of Grades 1, 2, or 4).

SA-240. Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Plate, Sheet, and Strip for Fusion-Welded Unfired Pressure Vessels (except for Grade B and in plate only).

A.S.T.M. B127–41T. Specifications for Nickel-Copper Alloy Plate, Sheet, and Strip (Plate only).

(*b*) Materials used for linings of inner shells, heads, or openings shall not be limited as to composition, but shall not be included in the wall thickness used in determining the allowable working pressure. Clad plates, irrespective of the cladding material, may be used for inner shells, nozzles, or other openings provided the carbon steel backing conforms to steel specifications accepted by the Code. Alloy cladding shall not be included in the wall thickness for which allowable working pressure is calculated.

UL-3(*a*). Design of shells of layer vessels may be based on prestress under Par. UL-3(*c*) for vessels to be operated at shell temperatures not in excess of 600 F. Openings shall not be permitted in any section of the shell for which the thickness is calculated on the basis of prestress, but non-prestressed cylindrical sections of shells containing openings may be welded to layer sections which do not contain openings, the thicknesses of which are calculated on the basis of prestress.

(*b*) For vessels in which prestress is not a basis of design, the maximum allowable working pressure shall be determined by the formulas in Par. U-20(*a*) and (*b*), in which thickness t to be used shall be the sum of the thicknesses of the individual layers comprising the shell (including the inner shell).

(*c*) When the method of construction is such as to produce circumferential compressive stresses on the inner shell at least equal to the operating pressure, and at the same time is such as to produce a favorable distribution of prestress throughout the vessel wall, the wall thickness may be determined by the use of the formula $t = \frac{pr}{se}$ in which t is the sum of the thicknesses of the individual layers comprising the shell (including the inner shell). Evidence of satisfactory prestress shall be made part of the permanent record of the vessel and recorded on the manufacturer's data report form.

UL-4(*a*). An aggregate average joint efficiency (E in Par. UL-3*c*) for the whole thickness of vessel wall shall be determined by adding the products of joint efficiencies and thicknesses of individual layers (including the inner shell), and dividing the sum by t, the whole thickness of the wall. The longitudinal joint efficiencies of individual layers and inner shell shall be determined by the existing rules of the Code, with the exceptions stated in Par. UL-4(*b*).

(*b*) The longitudinal welded seams in individual layers may be assigned an efficiency of 95 per cent, provided they are spaced around the cylinder so that no weld in one layer is offset circumferentially less than 3 in. or 10 deg (whichever is less) from a radial plane through the axis of the cylinder and the center of a longitudinal weld in any other layer. Any longitudinal seams located within the 3 in. or 10 deg spacing shall be assigned a joint efficiency of 85 per cent.

UL-5. All steel surfaces to be in contact shall be free of scale before assembly.

UL-6(*a*). All welded joints in heads except those specifically exempted in (*a*), (*b*), and (*c*) of Par. U-68(*b*) (1) and except those which attach the heads to the shell shall be stress-relieved and radiographed.

(*b*) For full hemispherical heads, with pressure on the concave side, the following formula shall be used for calculating the allowable working pressure:

$$P = \frac{2SEt}{R + 0.2t} \quad \text{or} \quad t = \frac{PR}{2SE - 0.2P}$$

The flanges (skirts) on hemispherical heads may be eliminated and if not eliminated the outer layers of the shell shall extend to the tangent lines of the head.

(*c*) When the thickness of the inner shell exceeds the limits stated in Pars. U-13(*c*) and U-76, the welds attaching the heads or end flanges to the inner shell shall be stress-relieved and the circumferential seams connecting the heads or flanges to the inner shell shall be radiographed. The thickness of circumferential welds for attaching heads or flanges and the combined thickness of circumferential welds for layers is not to be less than the minimum required thickness of a hemispherical head divided by the efficiency of the joint.

UL-7(*a*) Unreinforced openings in flanges or heads shall be limited to a maximum diameter of 1 in. No unreinforced openings shall be made in a circumferential weld.

(*b*) Any threaded connections made into a layer section must be made into a forging or casting welded into the vessel wall, the forging or casting providing the necessary reinforcement.

(*c*) A studded connection with a flat surface machined for a gasket upon a forging or casting may be used for attaching flanged fittings provided the studs are engaged in the forging or casting for a depth of at least $1\frac{1}{2}$ times the stud diameter. The forging or casting shall supply the required reinforcement.

(*d*) Except as provided in Par. UL-8, all openings in the shell section shall be reinforced. Connections in the shell wall may each consist of a forged or cast tube or fitting welded to all layers comprising the shell wall. The maximum inside diameter of the finished opening shall not exceed 25 per cent of the inside diameter of the shell. Openings of diameters in excess of 10 per cent of the inside diameter shall preferably be placed in the heads. Openings shall not be permitted in sections of the shell for which credit for prestress is taken.

UL-8(*a*) Telltale holes used in these vessels shall be not less than $\frac{1}{8}$ in. in diameter and shall extend to the inner shell. The number of telltale holes in each shell section shall be at least twice the number of plates comprising the first layer wrapped upon the inner shell. Half of the telltale holes in each shell section shall be located near each end of the shell section.

(*b*) When all circumferential seams are welded in the finished vessel to a thickness only equal to that of the inner shell no telltale holes are necessary.

UL-9(*a*). The hammer test of Par. U-77 need not be applied.

(*b*) After the heads or flanges have been welded to the inner shell with welds having a radial thickness equal to the thickness of the inner shell, either the circumferential welds shall be given a complete radiographic examination or the vessel shall be subjected to a hydrostatic pressure test for one hour at a pressure which will stress these welds in a longitudinal direction to the allowable unit working tensile stress of the inner shell material.

(*c*) Portions of vessels requiring stress-relief shall be stress-relieved after any welding repairs have been made, except that if such parts have been incorporated in a vessel careful peening may be used in place of stress-relief by heating.

(*d*) After each layer has been wrapped and welded it shall be hammer sound tested for tightness. No loose area greater than 40 deg, but not to exceed 12 in. circumferentially and 24 in. longitudinally, shall be permitted. The maximum radial gap between any two adjacent layers as measured at the ends of the shell sections shall not exceed 0.020 in. and the area of such gap measured in a plane at right angles to the vessel axis shall not exceed 0.060 sq in.

(*e*) A hydrostatic test shall be made in which the pressure is raised slowly to test pressure and not less than ten readings made of pressure and volume of the water pumped into the vessel. The volume pumped into the vessel shall be plotted in relation to the pressure and a curve defined by the plotted points. At low pressures, this curve may depart slightly from linearity. The upper portion of the curve shall be a straight line.

(*f*) The records of tests made under (*b*) and (*e*) shall be made a part of the permanent record of the pressure vessel and recorded on the manufacturer's data report form.

UL-10(*a*). Operators will qualify for making girth welds by passing the operator qualification tests prescribed in Section IX using 1 in. thick plates of steels in the appropriate group or groups.

(*b*) For layers or bands, detached test plates shall be made in accordance with the provisions of Par. U-68, except that they shall be welded using a backing strip of the same material. One test plate shall be provided for each 1000 ft of longitudinal seams in the layers or bands but need not exceed one for each vessel.

(*c*) For the inner shell, a detached test plate shall be prepared in accordance with Par. U-68, using the same welding procedure as in making the joints in the inner shell. Inner shell test plates are not required when electric-resistance welded or seamless pipe is used, in which case the inner shell shall be tested to a minimum of 80 per cent of the specified yield point of the material.

(*d*) For circumferential seams, the procedure qualification shall be made under Section IX using two plates of the thickness of the circumferential seam which need not exceed 2 in., and the plate shall be tested in the as-welded, stress-relieved, or heat-treated condition depending upon the treatment used in the finished seam of the vessel.

(*e*) When the test plate is made up of alloy material, the bend test requirement of Par. U-68(*f*) is reduced to 20 per cent minimum.

UL-11. The requirements of Par. U-72(*c*), (*d*), and (*e*) do not apply.

UL-12(*a*). The reinforcement built up on welded seams of the inner shell under Par. U-73 shall be removed flush with the plates on the outside and may be removed on the inside. If the equivalent of a double-welded butt joint is made by welding against a backing strip the reinforcement shall be removed but the backing strip may be left in place.

(*b*) The required reinforcement on welded seams of the layers or bands applies to the outsides only, and must be removed flush with the surface of the plates before applying the next band. The reinforcement need not be removed from the outermost band.

(*c*) The circumferential welds joining the shell sections to each other or to the heads or flanges may be of the double-welded butt type or the equivalent single-welded butt type using a backing strip. Welds of either type may be used for securing other pressure parts into the wall or heads of the vessel. Full penetration welds are required and the backing strips may be either removed or left in place.

(*d*) Circumferential welds shall be assigned the following maximum efficiencies:

(1) If radiographed and stress-relieved, 95 per cent;

(2) If neither X-rayed nor stress-relieved, 85 per cent.

(*e*) The provisions of Par. U-73(*f*) shall not apply.

UL-13. Vessels built in accordance with these rules shall be stamped under the Code symbol with the letters "UL."

BOOKS RECEIVED IN LIBRARY

ELEMENTARY STATISTICAL METHODS. By H. M. Walker. Henry Holt and Company, New York, N. Y., 1943. Linen, 6 × 9½ in., 368 pp., diagrams, charts, tables, $2.75. This textbook is based on courses given in Teachers College, Columbia University. The author has aimed at a clear, simple exposition that will make the text practically self-teaching, with attention to the development of underlying concepts and to interpretation. Emphasis is placed upon statistical techniques, the limitations and advantages of each, the assumptions underlying it, and the interpretations which can be made from it. Certain chapters have bibliographies.

ENGINEERS' DICTIONARY, SPANISH-ENGLISH AND ENGLISH-SPANISH. By L. A. Robb. John Wiley & Sons, Inc., New York, N. Y., Chapman & Hall, London, England, 1944. Fabrikoid, 5½ × 8 in., 423 pp., $6. This dictionary contains about ten thousand terms used in civil engineering, including many mechanical and electrical words, as well as geological, chemical, and other scientific terms. A special advantage of the book is that the Spanish vocabulary is South American Spanish, and the English is American.

ESSENTIALS OF PRECISION INSPECTION. By W. Mollard. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1944. Cloth, 8½ × 11 in., 207 pp., illus., diagrams, tables, $3. This manual offers a systematic course of instruction in the use of the instruments used in interchangeable manufacturing. The instruments used are described, methods of checking their accuracy given, and their uses for various purposes explained and illustrated by problems.

FLIGHT TESTING OF PRODUCTION AIRCRAFT. By J. A. C. Warren. Sir Isaac Pitman & Sons, London, England; Pitman Publishing Corporation, New York, N. Y., 1943. Cloth, 5½ × 9 in., 131 pp., illus., diagrams, charts, tables, $3. This manual presents the principles and purposes of the flight testing of production aircraft. The general faults that are likely to occur are described, and methods which are to be adopted in finding their causes are indicated.

FUNDAMENTALS OF VIBRATION STUDY. By R. G. Manley with a foreword by W. K. Wilson. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1942. Cloth, 5½ × 9 in., 124 pp., diagrams, charts, tables, $2.75. Fundamental principles underlying present-day vibration study are presented in such a way as to be readily assimilated by the busy engineer. Major topics considered are the physics of the simple vibrating system, damping and forced vibration, systems with two or more degrees of freedom, and the application of Fourier's analysis to complex vibrations.

GAS TURBINES AND JET PROPULSION FOR AIRCRAFT. By G. G. Smith, Aerosphere, Inc., New York, N. Y.; Flight Publishing Co., London, England, 1944. Paper, 5½ × 8½ in., 80 pp., illus., diagrams, $1.50. This little book discusses the various proposals that have been advanced for propelling aircraft by jets or by steam or gas turbines. The survey is as comprehensive as is possible at this time and is illustrated by drawings. The material originally appeared in *Flight*.

HANDLING PERSONALITY ADJUSTMENT IN INDUSTRY. By R. N. McMurry. Harper & Brothers, New York, N. Y., and London, England, 1944. Cloth, 5½ × 8 in., 297 pp., tables, $3. This interesting discussion of personnel problems in industry is written primarily for top executives. It points out some of the ways in which psychology and psychiatry can be utilized in determing the sources of some problems and in suggesting possible solutions for them. The book calls attention especially to the part played by personality and emotion in relations between employee and employer.

INDUSTRIAL MANAGEMENT. By A. S. Knowles and R. D. Thomson. The Macmillan Co., New York, N. Y., 1944. Cloth, 5½ × 8½ in., 791 pp., illus., diagrams, charts, tables, $4.50. The subject matter of this book is confined to topics of immediate concern to persons who must direct the work of others in manufacturing enterprizes. The six main divisions are: introduction; management of physical property; organization of the physical plant; management of manpower; production control; and cost control. Such topics as time and motion study may appear under two or more headings if pertinent. Practical problems are included which represent actual situations.

LIFE OF SIR J. J. THOMSON. By Lord Rayleigh. University Press, Cambridge, England; The Macmillan Co., New York, N. Y., 1943. Cloth, 5½ × 9 in., 299 pp., illus., tables, $6. Lord Rayleigh has written an excellent account of the life of the great physicist, in which is reviewed the epoch-making scientific work done at the Cavendish Laboratory by Thomson and his pupils. The human side of the man is also covered. Laymen, as well as scientists, will find the book full of interest.

MARINE COPPERSMITHING. By F. J. Carr. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1944. Cloth, 5¾ × 9 in., 195 pp., diagrams, charts, tables, $2. This practical manual on coppersmithing is a welcome addition to the scanty literature upon an important craft. The author describes tools and processes for all kinds of work, showing the ways of working that he believes the best and simplest. The illustrations add greatly to the text.

MATERIALS HANDBOOK, an Encyclopedia for Purchasing Agents, Engineers, Executives, and Foremen. By G. S. Brady. Fifth edition. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1944. Cloth, 5¾ × 9 in., 765 pp., charts, tables, maps, $5. This handbook is intended as a quick source of information on the characteristics of materials of industrial importance. It will be useful to purchasing agents, designers, executives, and others. The arrangement of this handbook is alphabetical, with a good index to trade names, synonyms, etc. The new edition has been carefully revised and is larger than preceding ones.

OCCUPATIONAL INDEX, vol. 8, nos. 1–5, January, April, July, October and Index, 1943. References 1–375. Occupational Index, Inc., New York University, New York, N. Y. Paper, 7 × 10 in., annual subscription. This bibliography, issued quarterly, contains annotated references to current pamphlets, books, and magazine articles containing information about opportunities in various occupations. Over three hundred publications are listed in 1943. The annotations are clear and informative. Indexes by author, title, and subject are provided. Both military and civilian occupations are covered.

OPTICAL WORKSHOP PRINCIPLES, being a translation of "Le Travail des Verres d'Optique de Précision." By C. Dévé with a preface by C. Fabry, translated by T. L. Tippell. Adam Hilger, London, England, 1943. Cloth, 5½ × 9 in., 306 pp., illus., diagrams, charts, tables, 20s. Obtainable in U.S.A. from Jarrell-Ash Company, Boston, Mass., $6. In this book special attention is paid to the actual technique of optical glassworking, to the manipulations of handworking, and the setting and adjustment of grinding and polishing machines. Stress is laid upon the fundamental processes that form the basis of all good workshop practice and on the theoretical reasons that govern their proper application. The book is a welcome addition to the scanty literature now available on the subject.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by A.S.M.E. members for a small handling charge. The Library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Harrison W. Craver, Director, Engineering Societies Library, 29 West 39th St., New York, N. Y.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Program for 1944 A.S.M.E. Semi-Annual Meeting at Pittsburgh, June 19–22

Sikorsky, Weaver, Newbury, Johnson, and Chen Among Speakers

THE technical program of the 1944 Semi-Annual Meeting of the American Society of Mechanical Engineers, to be held at Pittsburgh, Pennsylvania, June 19 to 22, with headquarters at the Hotel William Penn, has been released by the Committee on Meetings and Program charged with the conduct of all Society meetings. In co-operation with the Professional Divisions, the Technical Committees, and a Pittsburgh committee headed by R. J. S. Pigott, arrangements have been completed for twenty-one technical sessions which commence Monday, June 19 at 10:30 a.m. and run through Thursday afternoon. Because of the number of the sessions, many of them will run concurrently on the various days.

Plant Trips

On Tuesday evening at 6:30 p.m. the Railroad Division dinner will be held, while Wednesday evening will be devoted to the A.S.M.E. reception and dinner. Although every effort has been made to secure manuscripts of the technical papers in time for preprinting so that discussion can be prepared in advance of the meeting, pressure of war activities has delayed the authors in many cases in forwarding their texts to headquarters.

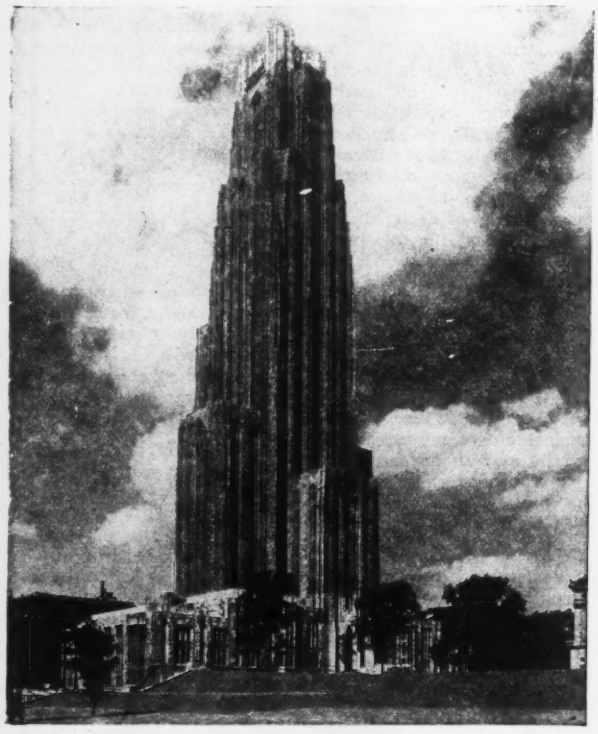
Even though war conditions have greatly restricted the opportunities for visiting plants of interest, the Pittsburgh Committee has been successful in arranging four trips of unique interest—one for each afternoon.

Keeping in mind this period of emergency, any individual contemplating one of these plant visits should come to the meeting, provided with satisfactory credentials. The plants of interest that will be visited are quite varied. For Monday afternoon, at 2:00 p.m., efforts are being made to arrange a trip to inspect a Floating Power Plant. On the return the Duquesne Brewing Company will be visited. The inspection trip to the Irvin Plant of the Carnegie-Illinois Steel Company will take place on Tuesday afternoon at 1:30 p.m. Wednesday's trip to the Forge Plant operated by the Aluminum Company of America for the Defense Plant Corporation at Canonsburg, will start at 12:00 noon. The Dravo shipyards will form the inspection trip on Thursday afternoon, at 2:00 p.m.

Business and Council Meetings

The semi-annual business meeting of the Society is scheduled for Monday afternoon, June 19, at 4:45 p.m.

The Executive Committee of the A.S.M.E.



CATHEDRAL OF LEARNING

(This unique building is the center of the University of Pittsburgh activities. It is a structure that "expresses, through the characteristic qualities of its architecture, the spirit or purpose of all that should go on within a university." The name was suggested partly by its Gothic architecture, and partly by the the idea that it is "a seat or central symbol of creativeness and of achievement in the Pittsburgh district." This is the tallest schoolhouse in the world. It rises to the height of 41 stories or 535 feet. The topmost roof deck is 1423 feet above sea level.)

Registration Fee for Non-Members at 1944 Semi-Annual Meeting

There will be a registration fee of $2 for nonmembers attending the 1944 A.S.M.E. Semi-Annual Meeting at Pittsburgh, Pa., June 19–22, 1944. For nonmembers wishing to attend just one session the fee will be $1. This is in accordance with the ruling of the Standing Committee on Meetings and Program.

Members wishing to bring nonmember guests may avoid this fee by writing to the Secretary of the Society before June 9 asking for a guest-attendance card for the Spring Meeting. The card, upon presentation by a guest, will be accepted in lieu of the registration fee. Guests are limited to *two per member*.

Council will hold its meeting on Sunday, June 18, at 9:30 a.m., preceding the official opening of the meeting on Monday. Also on Sunday the entire Council will meet at 2 p.m. The Council as a whole will again meet on Monday at 9:30 a.m.

The Nominating Committee will meet on Tuesday and Wednesday at 9:30 a.m. It will hold an open session on Tuesday at 10:30 a.m. to afford members opportunity to speak on behalf of candidates for the office of president, vice-president, and managers, after which the committee will make its selections to be voted on by members later in the year.

Women's Program

The Pittsburgh local steering committee has welcomed the opportunity for providing interesting and social activities for women attending the Pittsburgh meeting. As host to the women, the committee has arranged for all luncheons to be complimentary. Luncheon has been arranged at the Women's Club or Monday followed by a social gathering and cards. In the evening either a visit to KDKA Broadcasting Station or the Buhl Planetarium may be chosen.

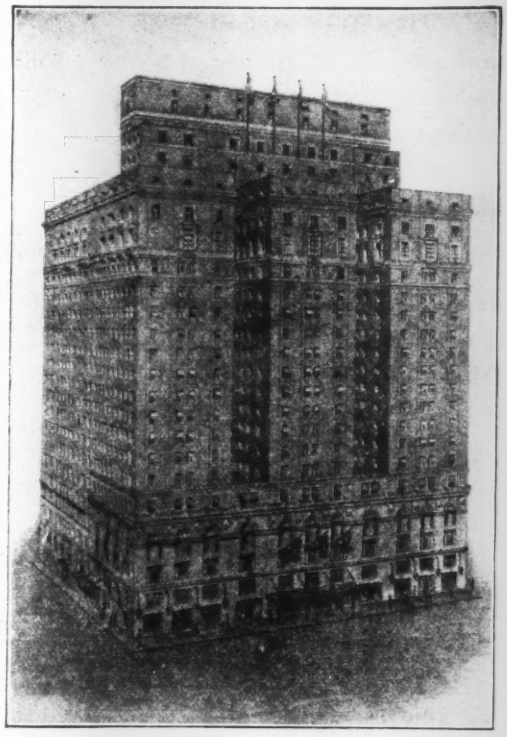
On Tuesday afternoon a Fashion Show at Horne's Department Store will be given. The fashion show will be preceded by luncheon at the Roosevelt Hotel.

Another luncheon will be served at the University Club on Wednesday followed by a visit to the Carnegie Institute and the Heinz Chapel. In the evening a reception will be held at the Hotel William Penn, followed by the A.S.M.E. dinner at which Igor Sikorsky will be the speaker. Thursday afternoon has been reserved for luncheon at the Pittsburgh Athletic Club, and subsequently a visit to the Stephen Foster Memorial or for those who enjoy it a baseball game may be seen at Forbes Field.

Luncheons and Dinners

Because of the opportunity the Semi-Annual Meeting affords, a number of luncheons and dinners have been arranged. The Management Division has a luncheon at 12:30 p.m. Monday with F. D. Newbury as speaker. On Tuesday there will be an A.S.M.E. luncheon at which Col. William A. Weaver, Executive Officer, Technical Division, Office of Chief of Ordnance, will be the speaker. In the evening the Railroad Division will have its dinner, when Col. J. Munroe Johnson, Director of the Office of Defense Transportation, will address the gathering. The luncheon on Wednesday will be addressed by K. Y. Chen.

In the evening the regular A.S.M.E. dinner will be held in the ballroom of the Hotel William Penn. Preceding the dinner, however, a reception will be held in the rooms adjacent to the ballroom on the seventeenth floor. On the last day of the convention, Thursday, luncheon has also been arranged.



HOTEL WILLIAM PENN, HEADQUARTERS A.S.M.E. SEMI-ANNUAL MEETING

Technical Sessions at 1944 A.S.M.E. Semi-Annual Meeting

Headquarters Hotel William Penn

MONDAY, JUNE 19

9:30 a.m.

Council Meeting

10:30 a.m.

Aviation—Applied Mechanics I

Strengthening of Circular Holes in Plates Under Edge Load, by Leo Beskin, Consolidated Vultee Aircraft Corporation, Allentown, Pa.

Quality Control—Management

Simplified Exposition of the Principles of Quality Control, by Joseph M. Juran, Assistant Administrator, Foreign Economic Administration, Washington, D. C.

Practical Control of Quality of Parts Made in Small Lots or Short Runs, by J. Manuele, director of quality control, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

Cutting of Metals

Machinability of Steel and its Relation to Yield Stress Ratios of the Same Tensility, by E. J. Janitsky, metallurgical laboratory, Carnegie-Illinois Steel Corporation, Chicago, Ill.

MONDAY (*continued*)

The Effect of Grain Size and Subzero Treatment on the Productivity of Four High-Speed Steels, by S. M. DePoy, metallurgist, Delco Products Division, General Motors Corporation, Dayton, Ohio

12:30 p.m.

Management Luncheon

The Value of Experiences in War Production Toward Problems of Reconversion, by F. D. Newbury, vice-president, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

2:00 p.m.

Plant Trips

Floating Power and Duquesne Brewery

2:30 p.m.

Aviation—Applied Mechanics II

The Matériel Command's Approach to the Flutter Problem, by Lee S. Wasserman, senior aeronautical engineer, Matériel Command, Wright Field, Dayton, Ohio

Bending Rigidity and Column Strength of Thin Web Sections, by Paul E. Sandorff, research engineer, Lockheed Aircraft Corporation, Burbank, Calif.

2:30 p.m.

Attitudes Toward Methods Improvement—Management

Management's Attitude Toward Methods Improvement, by J. Keith Louden, production manager, glass and closure division, Armstrong Cork Co., Lancaster, Pa.

Labor's Attitude Toward Methods Improvement, by Clinton S. Golden, vice-chairman, War Manpower Commission, Washington, D. C.

The Consultant's Attitude Toward Methods Improvement, by H. B. Maynard, president, Methods Engineering Council, Pittsburgh, Pa.

Lubrication

The Friction Properties of Various Lubricants at High Pressures, by John Boyd and B. P. Robertson, Research Laboratories, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

Investigation of Friction and Wear Under Quasi-Hydrodynamic Conditions, by R. G. Larsen and G. L. Perry, Shell Development Co., Emeryville, Calif.

4:45 p.m.

Business Meeting

Official Notice

A.S.M.E. Business Meeting

Note* CHANGE *in Time

THE Semi-Annual Business Meeting of the members of The American Society of Mechanical Engineers will be held Monday afternoon, June 19, 1944, at 4.45 p.m. at the Hotel William Penn, Pittsburgh, Pa., as a part of the Semi-Annual Meeting of the Society.

(*Signed*) C. E. DAVIES
Secretary

MONDAY (*continued*)

7:30 p.m.

Metals Engineering—Applied Mechanics

Machines for Testing Creep and Fracture of Metals at Very High Temperatures, by M. J. Manjoine, Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

Making Joints in Aluminum, by M. A. Miller, E. C. Hartman, and G. O. Hoglund, Aluminum Company of America, Pittsburgh, Pa.

Heat Transfer I

Panel Discussion on Recent Developments in Industrial Furnaces

Auspices Industrial Furnaces and Kilns Committee, Heat Transfer Division

William Adams, Jr., vice-president, Ajax Electric Co., Inc., Philadelphia, Pa. Fred S. Bloom, Bloom Engineering Co., Pittsburgh, Pa. C. Cone, Surface Combustion Corp., Toledo, Ohio

Slade Gamble, Lindberg Engineering Co., Chicago, Ill.

F. O. Hess, president, Selas Corporation of America, Philadelphia, Pa.

Matthew H. Mawhinney, Salem, Ohio

D. G. Merrill, Hartford-Empire Co., Hartford, Conn.

C. E. Peck, heating section, engineer, Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

J. T. Robson, Ferro Enamel Corp., allied engineering division, Cleveland, Ohio

B. J. Sayles, The Calorizing Co., Pittsburgh, Pa.

Haig Solakian, vice-president, The A. F. Holden Co., New Haven, Conn.

H. H. Watson, Pittsburgh Lectromelt Furnace Corp., Pittsburgh, Pa.

H. M. Webber, industrial heating division, General Electric Co., Schenectady, N. Y.

TUESDAY, JUNE 20

9:30 a.m.

Nominating Committee Meeting

Aviation—Industrial Instruments and Regulators—Petroleum

Stabilizing a Suction Relief Valve, by Ed S. Smith, Eclipse-Pioneer Division, Bendix Aviation Corporation, Bendix, N. J.

Experimental Studies in Fractionating Column Control, by L. H. Allen, Jr., American Viscose Corp., Marcus Hook, Pa.

Fuels I

The Fuel Investigation Precedes Power Plant Design, by E. C. Payne, Consolidation Coal Co., New York, N. Y.

Coal Segregation in Boiler Plants, by Arthur J. Stock, Stock Engineering Co., Cleveland, Ohio

Production Engineering—Metals Engineering

Spinning of Steel, by S. Boling, Canfield, Ohio

Induction Furnace—A New Tool for The Aluminum Foundry, by Manuel Tama, Ajax Engineering Co., Trenton, N. J.

9:30 a.m.

Railroad Division Executive Committee Meeting

TUESDAY (*continued*)

10:30 a.m.

Nominating Committee—Open Hearing

12:30 p.m.

Luncheon

Speaker: Col. William A. Weaver, executive officer, technical division, Office of Chief of Ordnance, Washington, D. C., will speak on "Army Ordnance in the Southwest Pacific"

1:30 p.m.

Trip to Irvin Plant

2:30 p.m.

Metals Engineering—Railroad

The Development and Trend in Modern Structural Materials for Railroad Rolling Stock, by S. H. Badgett, Passenger Car Division, Pressed Steel Car Co., Inc., Pittsburgh, Pa.

Structural Material for Railroads, by H. W. Gillett and F. L. Hoyt, Battelle Memorial Institute, Columbus, Ohio

Use of Aluminum in Railway Construction, by A. H. Woolen, engineer, Railway Division, Aluminum Co. of America, Pittsburgh, Pa.

Heat Transfer II

Heating-Up Time and Energy Losses of Furnaces, by V. Paschkis, Columbia University, New York, N. Y.

Economic Thickness of Insulation for Intermittent Operation, by V. Paschkis, Columbia University, C. E. Ernst, and C. B. Bradley, Johns Manville Co., New York, N. Y.

Draft Gear Action in Train Service, by O. R. Wikander, mechanical engineer, ring spring department, Edgewater Steel Co., Pittsburgh, Pa. (by title)

Production Engineering

High-Speed Milling of Aluminum and Magnesium, by P. Thut, The Todd Co., Rochester, N. Y.

Use of Negative Rake Tools in the Production of Aircraft, by J. Q. Holmes, master mechanic, eastern aircraft division, General Motors Corporation, Linden, N. J.

8:00 p.m.

Railroad

Railroads, by Colonel J. Monroe Johnson, director, Office of Defense Transportation, Washington, D. C.

Symposium on Adjustment of Floating, Corresponding, or Derivative Control Actions—Industrial Instruments and Regulators

Discussion by: F. D. Burns, The Hays Corp., Michigan City, Ind.; M. H. White, Atlantic Refining Co., Philadelphia, Pa.; J. G. Ziegler, Taylor Instrument Companies, Rochester, N. Y., and others.

Aviation—Wood Industries

Duramold Process, by Joseph A. Spricic, Duramold Div., Fairchild Engine and Airplane Corporation, New York, N. Y.

Developments in Interior Finishing of Wood Aircraft, by J. M. Stevens, Division of Fairchild Engine and Airplane Corporation, Fairchild Aircraft, Hagerstown, Md.

TUESDAY (*continued*)

Vibration Tests on High-Density Plywood, by Albert G. H. Dietz, Massachusetts Institute of Technology, Cambridge, Mass., and Henry Grinsfelder, senior chemist, Resinous Products and Chemical Co., Philadelphia, Pa.

Fuels II

Factors Affecting the Thickness of Slag on Furnace Wall Tubes, by W. T. Reid and P. Cohen, Bureau of Mines, Pittsburgh, Pa.

The War Problem of Increasing the Utilization of Small Anthracite, by J. F. Barkley and L. D. Schmidt, Bureau of Mines, Washington, D. C.

8:00 p.m.

Moving Pictures

WEDNESDAY, JUNE 21

9:30 a.m.

Nominating Committee

Aviation—Metals Engineering

Stepped Extrusions, by Kirby F. Thornton, Aluminum Co. of America, Pittsburgh, Pa.

The Effect of Combined High Temperature and High Humidity on the Corrosion of Samples of Various Metals, by B. W. Jones and W. L. Maucher, industrial control engineering division, General Electric Co., Schenectady, N. Y.

Power I

Package-Type Power Plants, by H. H. VanKennen, mechanical engineer, and Lester E. F. Wahrenburg, vice-president, Peter Loftus Organization, Pittsburgh, Pa.

Power Trains

Informal presentation of a discussion on "Power Trains" to be based on talks by:

C. M. Lafoon, manager, a-c generator engineering department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., who will discuss the general subject of portable power plants in the light of recent developments. Two plant sizes are under construction and such information as is available regarding the over-all design features will be presented.

Otto de Lorenzi, director of education, Combustion Engineering Co., Inc., New York, N. Y., who will discuss the boiler plant equipment provided for one of the plant sizes.

F. G. Ely, analytical engineer, The Babcock & Wilcox Co., New York, N. Y., who will discuss the boiler plant equipment provided for the other plant size.

Heat Transfer III

Countercurrent and Cross Flow Cooling-Tower Calculations, by M. P. Peet, Humble Oil and Refining Co., Dayton, Texas

Variable Heat Transfer Rate Correction in Multipass Exchangers—Shell Side Film Controlling, by K. A. Gardner, Griscom-Russell Co., New York, N. Y.

Visual Aids Program—Education and Training

Visual Aids Program of the U.S.O.E., by George H. Griffiths, U. S. Office of Education, Washington, D. C.

WEDNESDAY (*continued*)

New Three-Dimensional Visual Aid Devices, by John T. Rule, Massachusetts Institute of Technology, Cambridge, Mass.

Visual Aids Program of the Navy, by H. B. Roberts, Lieut. U.S.N.R., Training Film Branch, Bureau of Aeronautics, Washington, D. C.

12:00 Noon

Trip to Canonsburg

12:30 p.m.

Luncheon

Calvin W. Rice Lecture on What Postwar China Hopes for From the United States Engineers, by K. Y. Chen, China Defense Supplies, Inc., Washington, D. C.

2:30 p.m.

Symposium on Controlled Atmospheres for Metal Processing—Process Industries—Metals Engineering

Application of Controlled Atmospheres to Processing of Metals, by C. E. Peck, Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa.

Moisture Controlled Air in Metal Processing Using Lithium Chloride Air Treating Equipment, by Robert E. Wills, engineer, Surface Combustion, Toledo, Ohio

The Drying of Hydrogen by the Activated Alumina System, by G. L. Simpson, vice-president and general manager, Pittsburgh Lectrodryer Corporation, Pittsburgh, Pa.

Review of Art of Controlled Atmospheres, by Sam Tour, New York, N. Y.

Heat Transfer IV

The Design of Heaters for the Petroleum Industry, by J. H. Rickerman, M. W. Kellogg Co., New York, N. Y.

Experimental Confirmation of Predicted Water Freezing Rates, by R. E. Seban and A. L. London, Stanford University, Calif.

A.S.M.E. National Nominations

MEMBERS of The American Society of Mechanical Engineers are invited to appear before the A.S.M.E. Nominating Committee at its open meeting on Tuesday, June 20, 1944, at the Hotel William Penn, Pittsburgh, Pa., headquarters for the Semi-Annual Meeting of the Society. Any time between 10 to 12 a.m. and 2 to 4 p.m. on that day the Committee will be glad to hear any member express his views or discuss matters pertaining to the selection of nominees for elective offices in the A.S.M.E. for 1945.

The personnel of the Committee and other pertinent information on nominations was published on page 145 of the February, 1944, issue of MECHANICAL ENGINEERING, and members of the Society are urged to read this over to refresh their memories.

THE MELLON INSTITUTE IN PITTSBURGH

WEDNESDAY (*continued*)

Postwar Training

Committee on Education and Training for the Industries

Rehabilitation, by General Frank T. Hines, Veterans Bureau Headquarters, Washington, D. C.

Postwar Training, J. C. Wright, U. S. Department of Education, Washington, D. C.

6:30 p.m.

Reception and Dinner

Speaker: Igor I. Sikorsky, engineering manager, Sikorsky Aircraft, Bridgeport, Conn., on Direct Lift Aircraft

THURSDAY, JUNE 22

9:30 a.m.

Materials Handling I

A New Type of Screw Luffing Crane for Ship Building, by Gilbert H. Atwood, chief engineer, Crane and Bridge Department, Engineering Works Division, Dravo Corp., Pittsburgh, Pa.

Vibration at Work, by Herbert J. Flint, manager, Jeffrey Traylor Division, Jeffrey Manufacturing Co., Columbus, Ohio

Planning for Postwar Production, by A. F. Anjeskey, sales manager, Cleveland Tramrail Division, Cleveland Crane and Engineering Co., Wickliffe, Ohio

Aviation—Rubber and Plastics

Effect of High Relative Humidities in Producing Changes in Dimensions of Laminated Plastics, by A. C. Titus, Works Laboratory, General Electric Co., Schenectady, N. Y.

Use of Rubber and Synthetics for Sealing Aviation Fuel System Equipment, by T. R. Thoren, Thompson Aircraft Products Co., Cleveland, Ohio

Power II

Steam Turbine Designer's Reliance on Research and Experimental Laboratories, by C. C. Franck, Westinghouse Electric and Manufacturing Co., Philadelphia, Pa.

THURSDAY (*continued*)

12:30 p.m.

Luncheon

2:00 p.m.

Trip to Dravo Shipyards

2:30 p.m.

Materials Handling II

Materials Handling—A Field for Industrial Progress, by Randolph W. Mallick, Section Engineer, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

Forum on Materials Handling—A Tool of Production

Rubber and Plastics

Effect of Temperature and Humidity on Mechanical Properties of Cellulose-Acetate and Cellulose-Nitrate Plastic Sheets, by T. S. Lawton, Jr., T. S. Carswell, and H. K. Nason Plastics Division, Monsanto Chemical Co. Springfield, Mass.

Mechanical Rubber Goods as Used on Modern Aircraft, by E. G. Kimmich, Goodyear Tire and Rubber Co., Akron, Ohio

Hot Forming of Phenolic Laminates, by H. C. Guhl, Micarta Department, Westinghouse Electric and Manufacturing Co., Trafford, Pa.

Hydraulic

Cavitation Characteristics of Centrifugal Pumps, by A. J. Stepanoff, Ingersoll-Rand Co., Phillipsburg, N. J.

Some Characteristics of Rotary Pumps in Aviation Service, by R. J. S. Pigott, Gulf Research and Development Co., Pittsburgh, Pa.

Friction Factors for Pipe Flow, by Lewis F. Moody, Princeton University, Princeton, N. J.

E. S. N. E. Honors Sanford A. Moss

THE New England Award for 1944 of the Engineering Societies of New England was presented to Dr. Sanford A. Moss, fellow A.S.M.E., at its Annual Dinner, Boston, Mass., May 5, 1944. Dr. Moss is well known for his pioneer work on turbosuperchargers.

President's Page

A New Field of Opportunity

OUR Society, in its intimate relationship with industry, has taken an increasing interest in problems of industrial management. Many of our members have become officers of industrial corporations with broad managerial responsibilities. Others are definitely associated with industrial management in all its war or postwar planning and the execution of its plans. All are concerned with the service of industry to the people—which cannot be rendered by insulating the main factors in closed compartments. With the postwar challenge to industry and to our profession, our Management Division, of which J. M. Juran is now chairman, takes on added importance.

In the March issue of this magazine appeared a notable article by Fenton B. Turck and William E. Hill on "Scientific Methods of Distribution." The authors explained the need of applying the engineering techniques that have been so conspicuously successful in production to the process of distribution on which continued production at a high level depends. In this field of engineered distribution they see 8000 potential jobs for engineers—an outstanding opportunity for service.

The responses to this article have been impressive. They have come from responsible executives of both large and small businesses, from engineers of high standing in the profession, from engineering schools. Some believe the potential benefits from the application of engineering techniques to this field are comparable with those achieved by scientific management in the field of production. Industry is recognizing the vital importance of reducing distribution costs and hence prices of consumers' goods, as essential to maintaining a high level of production.

Within our Management Division a special Committee on Distribution has been set up with Mr. Turck as chairman. Suggestions will be welcomed. How may our profession best meet this new challenge? What changes does it call for in the curricula of our engineering schools? What special training for graduate engineers? What part should such training have in the plans for the education of returning soldiers and of technicians released from service in war industries?

Consideration and opening of this special field of opportunity for engineers, it seems to me, constitute a phase of the postwar problem facing our profession that I have been trying to emphasize—the need of raising our sights, of broadening our service to industry and the nation, of opening doors wider to youth, in the period of great potential industrial expansion that lies ahead.

Design, production, distribution—these are interdependent, inseparable phases of industry. Whatever instruments we play in the industrial orchestra, we are players in a group whose music must be blended if a symphony is to result. In this kind of orchestra one's technique may be applied variously—and one may be a potential conductor. Every player, however, must be conscious of the whole.

(Signed) R. M. GATES, *President, A.S.M.E.*

National Meeting of A.S.M.E. Applied Mechanics Division, Chicago, Ill., June 16-17

THE eleventh National Meeting of the Applied Mechanics Division, The American Society of Mechanical Engineers, will be held at Chicago, Ill., June 16-17, with headquarters at the La Salle Hotel. Members of the Society who wish to take in the Semi-Annual Meeting, which will be held at Pittsburgh beginning Monday of the following week, will have ample time to make the trip from Chicago to Pittsburgh over the week end.

Local Committees Plan Events

The Applied Mechanics Meeting is being held under the auspices of the Illinois Institute of Technology and the Chicago Section, A.S.M.E. The chairman of the local committee is C. O. Harris, Illinois Institute of Technology, with whom are serving F. D. Cotterman, Crane Company; C. O. Dohrenwend, Armour Research Foundation; L. V. Griffis, Illinois Institute of Technology; A. H. Jens, Springfield Fire and Marine Insurance Company; V. L. Streeter, Illinois Institute of Technology; and W. E. Wilson, Armour Research Foundation.

Acting for the Chicago Section are J. P. Magos, chairman, and F. B. Orr, secretary-treasurer.

Technical Sessions

Three technical sessions, a dinner, and an inspection trip make up the program of the meeting. On Friday, June 16, the morning session will be devoted to the subject of elasticity with three papers under discussion. The general subjects of the Friday afternoon session are plastic flow and repeated stresses, and of the Saturday morning session, electrical, optical, and numerical stress analysis.

Moore to Speak at Dinner

Prof. H. F. Moore, member A.S.M.E., will be the speaker at the annual dinner, which is to be held at the La Salle Hotel on Friday evening. Professor Moore will talk about five notable figures in applied mechanics of materials. Reservations for the dinner should be sent to Prof. V. L. Streeter, Illinois Institute of Technology, Chicago 16, Ill., not later than June 10.

Inspection Trip

Saturday afternoon will be devoted to an inspection trip to the laboratories and facilities of the Illinois Institute of Technology and the Armour Research Foundation.

The detailed program follows:

Reserve Your Hotel Room Now!

IT cannot be said too often or stressed too urgently that hotel rooms are scarce—reserve yours immediately for the meeting. Reservations may always be canceled but it is practically impossible to get a room at the last minute. So before you do anything else, write *immediately* to make your reservation.

La Salle Hotel in Chicago is headquarters for the meeting and offers the most convenient accommodations.

Single room with bath, $3.30, 3.85, 4.40, 5.50

Double room with bath, $4.40, 4.95, 5.50, 6.60

Double room with bath (twin beds), $5.50, 6.60, 7.70

Reservations for rooms should be made directly with the reservation department of the hotel at the *earliest possible moment.*

The La Salle Hotel is at the corner of La Salle and Madison Streets and is easily accessible from Union Station and La Salle Street Station.

Friday, June 16

10:00 a.m.

Elasticity

Chairman: H. Poritsky, General Electric Company

Recorder: L. F. Welanetz, U. S. Naval Academy, Annapolis

Stresses in a Reinforced Monocoque Cylinder Under Concentrated Symmetric Transverse Loads, by N. J. Hoff, Polytechnic Institute of Brooklyn.

Application of the Fourier Method to the Solution of Certain Boundary Problems in the Theory of Elasticity, by G. Pickett, Portland Cement Association, Chicago, Ill.

The Bending of the Clamped Sectorial Plate, by G. Carrier, Cornell University.

2:00 p.m.

Plastic Flow and Repeated Stress

Chairman: L. E. Grinter, Illinois Institute of Technology

Recorder: M. Sadowsky, Illinois Institute of Technology

The Drawing of Thin-Walled Tubing With a Moving Mandrel Through a Single Stationary Die, by G. Sachs, J. D. Lubahn, and D. F. Tracy, Case School of Applied Science.

Theory of Drawing of Wires, by E. A. Davis and S. J. Dokos, Westinghouse Research Laboratories.

High-Speed Tension Tests With Particular Reference to the Yield Point of Mild Steel, by M. J. Manjoine, Westinghouse Research Laboratories.

FRIDAY (*continued*)

7:00 p.m.

Dinner, La Salle Hotel

Speaker: Professor H. F. Moore, on "Five Notable Figures in Applied Mechanics of Materials."

Reservations for the dinner accompanied by check ($3.50 per plate) should be sent to Professor V. L. Streeter, Illinois Institute of Technology, Chicago 16, *not later than June 10.*

Saturday, June 17

9:30 a.m.

Electrical, Optical, and Numerical Stress Analysis

Chairman: R. Eksergian, Edward G. Budd Manufacturing Company

Recorder: M. F. Spotts, Northwestern Technological Institute

Moment Distribution Analysis for Three-Dimensional Pipe Structures, by R. C. DeHart, Standard Oil Company (Indiana)

Equivalent Circuits of the Elastic Field, by G. Kron, General Electric Company

Numerical and Network Analyzer Solutions of the Equivalent Circuits for the Elastic Field, by G. K. Carter, General Electric Company

Studies in Three-Dimensional Photoelasticity: A Method for the Determination of Torsional Stress, by M. M. Frocht, Carnegie Institute of Technology

2:00 p.m.

Inspection Trip

The Laboratories and Facilities of the Illinois Institute of Technology and the Armour Research Foundation

Headquarters and Accommodations

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Local Committee

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F. D. Cotterman, Crane Company

C. O. Dohrenwend, Armour Research Foundation

L. V. Griffis, Illinois Institute of Technology

A. H. Jens, Springfield Fire and Marine Insurance Co.

V. L. Streeter, Illinois Institute of Technology

W. E. Wilson, Armour Research Foundation

Chicago Section A.S.M.E.

Chairman: J. P. Magos, research and development Laboratory, Crane Company

Secretary-Treasurer: F. B. Orr, Illinois Maintenance Company

Informal Meeting of the A.S.M.E. Council

At Spring Meeting, Birmingham, April 3

AN informal meeting of the Council of The American Society of Mechanical Engineers was held at the Tutwiler Hotel, Birmingham, Ala., Apr. 3, 1944, in connection with the Spring Meeting of the Society. There were present: R. M. Gates, president, who presided; Joseph W. Eshelman, Jonathan A. Noyes, and Ford L. Wilkinson, Jr., vice-presidents; Thomas S. McEwan, Roscoe W. Morton, and Albert E. White, managers; E. W. O'Brien (Board of Honors and Awards), S. R. Beitler, J. A. Keeth, and S. D. Moxley (Local Sections), R. A. North (Meetings and Program), and W. M. Sheehan (Professional Divisions); T. W. Babcock, Agenda Chairman, 1944 Sections Conference, and T. M. Francis, guests; and Col. C. E. Davies, secretary.

Secretary and President Report

The Secretary reported plans of the Committee on Engineering Opportunities and, with the President, on conferences held to work out a program to review some of the difficulties of the young engineer in industry. The President reported that plans were being perfected for an endowment-fund campaign and on the program for membership development, and told of his visits to sections and talks with industrial executives on the work of the Society.

Professional Divisions

For the Committee on Professional Divisions, W. M. Sheehan presented recommendations of the Metals Engineering Division that a representative of the American Society for Metals (A.S.M.) be appointed on the A.S.M.E. Handbook Committee and that a member of the A.S.M.E. be appointed on the A.S.M. Handbook Committee, in order to insure cooperation and avoid duplication.

He also presented a suggestion that the divisions set up educational committees to assist engineering schools in setting up curricula. (Action on the suggestion was taken at the April 14 meeting of the Executive Committee of the Council.)

Delegates Conference

W. W. Babcock, chairman of the Agenda Committee for the 1944 Delegates Conferences, announced that items for the agenda must be received by July 1.

Approval was voted of a subcommittee to supervise the operations of the working committee of the A.S.M.E. Handbook on Metals, consisting of J. H. Romann, T. H. Wickenden, E. Dixon, and H. B. Lewis, ex-officio.

Educational Committees

The Committee approved the recommendation that the Committee on Education and Training for the Industries be asked to review the suggestion (see report of Birmingham meeting of the Council) that each division establish educational committees to assist engineering schools in the formulation of their curricula and educational processes.

Lecturers Nominated

Confirmation was voted of letter-ballot approval of the nominations of Dr. Lionel S. Marks, Dr. Stephen P. Timoshenko, and Dr. Zay Jeffries as Society lecturers, and of the appropriation of $3000 for conducting the lecture program.

Student Branches

The Committee on Relations With Colleges was encouraged to modify its rules governing participation of student branches in local conferences because of changing conditions due to the war.

Manufacturing Engineering Committee

A report of the Manufacturing Engineering Committee was received.

Status of the Engineer

Approval was voted of the program of the Joint Committee on the Status of the Engineer and an appropriation to carry on the work of the Committee was approved.

Group Delegates Conference

It was voted to adopt the prepared statements of the Council actions on the recommendations of the 1943 Group Delegates Conference. Copies of the statements have been sent to the sections and may be had on request to the Secretary.

Postwar Planning

The Executive Committee, at its meeting in Toronto, October 2, 1943, made specific recommendations to several of the Society's committees and agencies about postwar planning. These recommendations, with Executive Committee actions, follow:

(1) *Review probable financial problems that would occur as war activities decrease, with a program for meeting them.*

The Executive and Finance Committee have increased the amount of surplus to be reached in 1945 and at suitable times will consider budgets to be put into effect quickly, if emergency requires. No further action is necessary at this time.

(2) *Develop a constructive plan for expanding the staff to meet increased demands in the postwar period.*

This was referred to Alfred Iddles, chairman of the Committee on Society Office Operation, who conferred with the Chairman of the Committee on Society Organization Structure, and submitted a report thereon. No further action is necessary now.

(3) *Stimulate program-making and publication activities to include discussions of postwar planning problems.*

Actions of A.S.M.E. Executive Committee

At Meeting in Society Headquarters, April 14

THE Executive Committee of the Council of The American Society of Mechanical Engineers met in the rooms of the Society on April 14, 1944. There were present: R. M. Gates, chairman, W. J. Wohlenberg, vice-chairman, Alton C. Chick, D. W. R. Morgan, and A. R. Stevenson, Jr., of the Committee; J. J. Swan (Finance), W. M. Sheehan (Professional Divisions); W. G. Christy and R. F. Gagg, Council members; G. J. Nicastro, chairman, Nominating Committee; Col. C. E. Davies, Secretary; and Ernest Hartford, Executive Assistant Secretary.

Richards Memorial Award

Howard E. Degler, national president, Pi Tau Sigma, in a letter to the Board of Honors and Awards, invited the Society to sponsor the Richards Memorial Award, named for the founder of Pi Tau Sigma. The award is a medal or cash or both, presented to the "mechanical engineer (45 or under) for outstanding achievement within 20 or 25 years of graduation." The Council voted to accept responsibility of selecting recipients for the Richards Memorial Award, provided the Society had no responsibility for the financial administration of the funds connected with the award.

Research on Furnace Performance

A co-operative agreement between Battelle Memorial Institute and the Society covering a research investigation on the subject of the correlation of data on furnace performance with furnace geometry was approved.

Research on Internal-Combustion Engines

Appointment was authorized of a new Special Research Committee on Internal-Combustion Engines "to prosecute, correlate, analyze, and report on research relating to efficiency, reliability, maintenance, and operating conditions of internal-combustion engines."

Steam-Turbine Standards

Reappointment was approved of members of the Special Committee on Standardization of Steam Turbines, discharged Dec. 3, 1943, to constitute a committee bearing the same name to represent the Society in negotiations with a similar A.I.E.E. committee and the publication of a separate or joint report. The committee consists of K. M. Irwin, chairman, G. A. Gaffert, secretary, R. C. Allen, C. B. Campbell, A. G. Christie, E. H. Krieg, A. L. Penniman, Jr., W. F. Ryan, and G. B. Warren.

Resolution of Thanks

A resolution of thanks, adopted at the Spring Meeting, Birmingham, Ala., Apr. 3–5, 1944, was approved.

Applied Mechanics Meeting

Approval was voted of a meeting of the Applied Mechanics Division, Illinois Institute of Technology, Chicago, Ill., June 16-17, 1944.

Metals Handbooks

The appointments of J. H. Romann and H. B. Lewis as A.S.M.E. representatives on the A.S.M. Handbook were approved.

This was referred to the Board on Technology on Dec. 8, 1943, which has not met since. The Executive Committee encourages the Committee on Engineering Opportunities to stimulate discussions of postwar problems by divisions and sections.

(4) *Determine the steps to be taken by the Society to support, during peacetime, continuous research and development in design of armament and in planning the use of manpower for an emergency.*

This was referred to the War Production Committee on Oct. 4, 1943, and on Dec. 1, 1943, that committee "voted to keep this subject permanently on the agenda of future meetings of the committee." Officers of the Society discussed this with Major General L. H. Campbell, Jr., Chief of Ordnance, on April 12.

(5) *Request the Engineering Societies Personnel Service to consider policies and procedures to be followed in aiding individual members to shift from war activities to peace activities.*

A Special Committee on Employment Clearing House has been appointed, consisting of J. E. Walters, chairman, M. M. Boring, and N. H. Memory.

(6) *Ask the United Engineering Trustees, Inc., to give immediate attention to general plans for improving the Engineering Societies Building or for securing a new building.*

This was referred to the A.S.M.E. representatives on the U.E.T. who reported that this had been considered by the U.E.T. at a meeting on Jan. 27, 1944, and that "the Trustees will keep the subject in mind for consideration at such time as it may seem to be practical."

(7) *Develop an active program of international relations because the reconstruction and rehabilitation of foreign countries offer excellent opportunities for engineering activities.*

The Secretary, to whom this item was assigned, has, during the past six months, explored the general matter of developing international relations among engineers. There have been informal discussions and correspondence with British and Russian engineers, with officials about China, and with the coordinator of Inter-American affairs about Latin America.

The Secretary has come to the conclusion that there is a tremendous opportunity for the engineering profession to be helpful in a postwar world by developing intimate relations with the engineers of the world. Such a program will be costly in staff, time, and member effort and if entered upon should have the approval of the members. The Secretary is marshaling his facts and preparing a program for discussion by the Executive Committee.

The Secretary recommends that a number of individuals be appointed to review his recommendations and comment on them to the Executive Committee. The personnel might include: William A. Hanley, William L. Batt, Warren H. McBryde, Col. P. R. Faymonville, Clarke Freeman, William F. Durand, and Harvey N. Davis.

Death of Geo. A. Orrok

The Committee noted with deep regret the death on April 6, 1944, of Geo. A. Orrok, honorary member and former member of the Council. A letter of condolence and tribute, on behalf of the Society, was sent to the family of Mr. Orrok.

Ordnance Advisory Committee

Authorization was voted of the establishment of an Ordnance Advisory Committee and the appointment of a committee of three consisting of President Gates, Past-President Coes, and Col. James L. Walsh to formulate detailed plans.

Appointments

The following appointments were noted for the record:

Professional Divisions, Douglas Hubert, Junior Adviser (two years).

Membership Development, N. O. Wynkoop, chairman, W. M. Sheehan (Professional Divisions), and H. E. Degler (Relations With Colleges).

Status of the Engineer, Elliott Dunlap Smith, chairman, R. E. Doherty, and P. T. Onderdonk.

Employment Clearing House, J. E. Walters, chairman, M. M. Boring, and N. H. Memory.

Rotative Project Fund, D. S. Walker, chairman.

War Honors, W. H. McBryde, chairman, E. W. O'Brien (Board of Honors), and J. M. Talbot (Professional Divisions).

Special Research Committee on Furnace Performance Factors, John R. Michel.

Sectional Committee on Rotating Electric Machinery, John R. Hageman; alternate, Charles D. Wilson.

Joint Conference Committee on Plan for Organization of Engineering Profession as a Whole, Harold V. Coes, chairman, Alfred Iddles, and P. T. Onderdonk.

American Academy of Political and Social Science, Annual Meeting, Philadelphia, April 14-15, 1944, representatives, W. H. Fulweiler, L. N. Gulick, and K. M. Irwin.

Engineering Society of Cincinnati, Dedication of New Building, March 13, 1944, representative, F. L. Wilkinson, Jr.

Among the Local Sections

President Gates at St. Louis Leads Discussion on Postwar Opportunities

Cross Section of Ideas on Education, Economics, Industrial Enterprise, Management, and Kindred Subjects Presented by Outstanding Speakers

ST. LOUIS members and their friends were hosts to Dr. Robert M. Gates, President of the Society, at a dinner held in the Park Plaza Hotel, March 16. In outlining his ideas he made clear that the immediate future holds an unprecedented opportunity for service, and that the Society must encourage in every way individual development and improvement of engineers, so they will be better able to serve society in a co-operative way. Engineers will be seeking the best answers to a group of problems which might be outlined as follows: Re-employment of service men, conversion of industries to civilian services, the need in industries for engineers and the training and advancement of partly trained engineers. The Society has the human potential to solve these problems, and to their solution members must contribute all we have, using service as a new standard of leadership.

In response to Dr. Gates' desire that the discussion which followed his remarks give a cross-sectional view of the problem, Dean Langsdorf of Washington University took up engineering education as a phase of the subject, and noted that there was a lot of "crystal gazing" going on. Much of this, he said, presumed infinite discontinuity in progress rather than recognizing that the seeds of change have been planted in the era before, and that progress is gradual.

The Dean emphasized the degeneration and shortcomings of our elementary and secondary education, which is being pursued on the basis of interest at the expense of substance. He advocated squeezing out the water, so to speak, so that the colleges can do the job of adequately covering the two phases of an engineering education, which are, first, the scientific and technological, and, second, the humanistic and sociological. After the war the boys re-entering the universities will have a new outlook; the graduates of accelerated courses will require additional specialized training (because these courses have been more or less failures); and the co-operation of industry will be required as never before.

Mr. Walter Siegerist, president, The Medart Company, pointed out the severe state of economic unbalance in which industry finds itself. A sympton of the unbalance is reflected in the rising cost of living and variation in amount of goods per unit of wages. All engineers are also citizens and must have an interest in what our representatives are doing in the legislative halls. Our representatives are of all kinds and frequently are in the dark and seeking information on what industry needs.

Mr. David Larkin, vice-president and general manager of Broderick & Bascom, declared there is a great opportunity for industrial engineers and engineers in industrial management, and the years will see engineers rising to strong positions in management. Much loose talk is being made about industry postwar planning, but it will be individual planning, not collective planning. Planning is difficult until peace is made and the question is, how soon? It might be three years or five years. Then will come the problems of foreign competition, shipping, and manufacture which will have to be solved. There is not likely to be a depression for at least five years.

Others participating in the discussion were: Mr. Kirby, Midwest Piping; Mr. Farquhar, American Steel Foundries; Mr. Tenny, Union Electric Co.; Mr. Springe, Combustion Engineering Co.; Mr. Thumser, Monsanto Chemical; Mr. Bryan, St. Louis Public Service Co., and others.

Prof. F. K. Morris Speaks at Boston Section

On April 13, the Boston Section held a meeting at the University Club, Boston, Mass., to hear Prof. Frederick K. Morris give an excellent talk on "The War in the Orient." Eighty-five members and guests were in attendance.

Future Solar Heating at Chicago Junior Session

W. C. Knopf, Jr., presented a talk on "Solar Heating in the Home of the Future," before 70 members of the Chicago Junior Section at a meeting held on April 10. Mr. Knopf reviewed the problems encountered and applications of the solar heating principle of the future, using colored slides to illustrate his subject. Before the meeting adjourned, members viewed the motion picture, "War Department Report."

Chicago Section Holds Joint Meeting With W.S.E. Members

A joint transportation division meeting of the Chicago Section and members of the W.S.E. was held on April 24, at the Y.M.C.A., 19 S. La Salle Street, Chicago, Ill. The program featured Prof. John I. Yellott as guest speaker, who gave an excellent review on "Basic Thermal Aspects of Propulsion Equipment." The mechanics of propulsion, efficiencies and characteristics of motive-power system for airplanes, locomotives, ships, and automotive vehicles were discussed, and finally the possibilities of gas turbine and jet propulsion were explained.

Central Indiana Members Welcome Dean Solberg

Chairman R. B. Bass of the Central Indiana Section reported that everyone at the April 21 meeting spoke highly of the paper, "Modern Steam-Generating Units," presented by the evening's guest speaker, Prof. H. L. Solberg, Dean, School of Mechanical Engineering, Purdue University. Professor Solberg illustrated his talk with attractive slides. Prior to his comments, the election of officers and members of the Executive Committee were announced as follows: M. E. Bechtold, chairman, D. P. Morse, vice-chairman, and Ferdinand Jehle, secretary-treasurer; members of the Executive Committee, Prof. C. Wischmeyer, R. B. Bass, G. L. Fowler, and Prof. H. L. Solberg.

Dr. W. E. Wickenden Defines Engineering Profession at Columbus Section

Taking as his topic, "The Engineer Needs His Profession," Dr. W. E. Wickenden, president, Case School of Applied Science, Cleveland, Ohio, on March 31, gave a group of A.S.M.E. and A.I.E.E. members some comprehensive facts as to why an engineer should become a member of a professional society. Dr. Wickenden's suggestions were well received by the seventy-five persons who attended the meeting.

Lundbye-Processed Cutting Tools Discussed at Dayton

The April 17 joint meeting of the Dayton Section and the Tool Engineers concerned itself with the same paper presented before the A.S.M.E. Spring Meeting, i.e., "Cutting Tools Chrome-Plated by the Lundbye Process." The paper was discussed by Axel Lundbye and thoroughly enjoyed by the 100 members and guests in attendance.

Steam-Generation Problems Reviewed at Louisville

As its guest speaker at the March 30 dinner meeting, the Louisville Section chose A. G. Rosenbaum of the Louisville Gas & Electric Company. Mr. Rosenbaum described present-day problems of steam generation. After his talk a lively round-table discussion was held.

Prof. T. T. Read Addresses Junior Metropolitan Group

On Tuesday, April 25, the Junior Group of the Metropolitan Section held a dinner meeting attended by about a hundred young engineers interested in hearing Prof. Thomas T. Read of Columbia University talk on "Postwar Opportunities for American Engineers in South America and Asia." Professor Read made it quite clear that there would be limited opportunities but "that if one goes abroad to find the doughnut, one will find only the hole." During the discussion following the talk young engineers from abroad expressed the opinion that the satisfaction in these postwar jobs would be found in the adventure of them and in the contribution to world betterment rather than in premature comfort or in security.

Prof. H. G. Thuesen Speaks at Mid-Continent

The subject, "Job Design," was discussed by Prof. H. G. Thuesen before an absorbed gathering on April 20 of the Mid-Continent Section and the Engineers Club of Tulsa, in the Chamber of Commerce Room, Tulsa Building, Tulsa, Okla. A stimulating discussion followed Professor Thuesen's talk.

S. D. Moxley and J. Perkins Speak at Philadelphia

"Latest Developments in the Field of Centrifugal Castings," a subject considered of vital importance to the casting industry, was discussed by S. D. Moxley and John Perkins, at at a dinner meeting of the Philadelphia Section in the Engineers Club, Philadelphia, on April 25. The symposium was very interesting and capably handled by Mr. Moxley, who is chief engineer of the American Cast Iron Pipe Company, Birmingham, Ala., and Mr. Perkins, assistant foundry superintendent, Ford Motor Company of Canada, Windsor, Ont Prior to the meeting, officers for the year 1944–1945 were elected as follows: Frank W. Miller, chairman; Justin J. McCarthy, vice-chairman; Sidney T. Mackenzie, secretary-treasurer, and members of the executive committee —Lee N. Gulick, retiring chairman, and Benjamin W. Webb.

Fiberglas Discussed Before Providence Members

"The Miracle of Glass," was the topic of the April 4 meeting of the Providence Section, at which John McCabe of Owens Corning Fiberglas Corporation expertly covered the process of flexible glass now known as "Fiberglas." Mr. McCabe illustrated his talk with motion pictures.

South Texas Section Sponsors Symposium on Postwar Work

A symposium on postwar employment was held by the South Texas Section, which acted as host to the Houston Section of the A.I.E.E., in the Rice Hotel, Houston, Tex., on March 28. The guest speakers were President Gates John R. Suman, vice-president Humble Oil & Refining Company, and Fred Staacke, general commercial superintendent, Houston Lighting & Power Company. Mr. Suman spoke on "Grass Roots Approach to Postwar Employment," after which brief but constructive ideas were presented by Frank Austin, vice-president, Houston Lighting and Power Company; Commander M. I. Kearns, Brown Shipbuilding Company; F. W. Warren, assistant to the president, Reed Roller Bit Company, and C. L. Orr, Texas Gulf Sulphur Company.

A.S.M.E. Student Award Made at Utah Section

Presentation of the A.S.M.E. Student Award was made by Dr. W. J. Cope at the January 24 meeting of the Utah Section to Tom Lucas, who was adjudged the outstanding senior mechanical in the A.S.M.E. Student Branch, Utah University. After the presentation, Wayne B. Hales, head of physics department, Brigham Young University, gave an illustrated lecture on "Long-Range Strategic Weather Forecasting." Mr. Hales briefly traced the history and development of long-range weather forecasting, and then cited the importance of its use in the war effort.

This Section held a meeting on March 27, for the purpose of hearing Fred H. Richardson speak on the subject of "Unionization of Engineers." Mr. Richardson, who is consulting engineer for the Portland Cement Company of Utah, impressed those attending with his suggestions for a national organization in the engineering field.

Navy Cross Winner Speaks to Audience of 200 at Washington, D. C.

Commander R. J. Moore, U.S.N., who recently won the Navy Cross for his daring

feats in sinking Japanese naval and merchant vessels honored members of the Washington, D. C., Section by his presence at their April 10 meeting. Commander Moore spoke on the subject of "Principles of Submarine Construction and Operation," which, despite naval restrictions, was so well arranged and related that it proved exceedingly interesting to the two hundred members and guests who were in attendance.

Waterbury Section Hears About Production Control

"Tremendous Trifles in Production Control," was the subject discussed at the April 20 meeting of the Waterbury Section. Carlos de Zafra described the problems of a technical consultant in this field and their solutions the necessity of combining practical experience with theoretical knowledge, and consideration of physical fitness of workers for the right job.

Western Massachusetts Has Fire Protection Session

Following the regular monthly dinner meeting, 55 members and guests of Western Massachusetts Section met on April 18 to hear a paper on "The Hydraulics of Fire Protection," presented by Wilbur Connor, assistant chief engineer, Inspection Department, Associated Factory Mutual Insurance Companies, Boston, Mass. Mr. Connor showed slides of sprinkler systems, including the wet pipe, dry pipe, and deluge types.

He also showed some most instructive moving pictures of the various causes of fire, and their prevention.

Turboblowers, Axial Compressors, and Gas Turbines Reviewed at W. Virginia Section

An enthusiastic audience consisting of 275 members and guests of the West Virginia Section and the Charleston Chapter of the A.I.Ch.E. on March 28 heard A. E. Caudle, engineer of the blower and compressor department, Allis-Chalmers Manufacturing Company, Milwaukee, Wis., give an illustrated account of "Centrifugal (Turbo) Blowers and Axial Compressors," and then speak briefly on "The Gas Turbine." Mr. Caudle reviewed the history and development of blowers and compressors, their theory, operation, application, and drives. The success of the gas turbine, he explained, was made possible first by the development of an efficient air compressor, capable of delivering the large amounts of air required, and then by the development of the modern heat-resisting stainless steels required to withstand the high temperatures required for efficient operation of the turbine.

Most of the present gas turbines, he said, have an inlet temperature of 1000 F, while 1200 F or more may soon be realized. Prior to the meeting, a dinner was held in honor of Mr. Caudle, and R. L. Halsted, West Virginia Allis-Chalmers representative.

With the Student Branches

Film "Thermodynamics" Shown at Arkansas Branch

An extremely interesting motion picture entitled "Thermodynamics," illustrating heat transfer in various modern engines, was enjoyed on April 3, by members of the ARKANSAS BRANCH.

At the April 7 meeting of CALIFORNIA TECH BRANCH, members discussed plans for a tour of beach installations and fixtures, and exchanged ideas for the contemplated membership drive. Moving pictures were then enjoyed by the 29 members and guests present.

German Use of Magnesium Noted by Professor Dorn in California Talk

Prof. J. E. Dorn, considered one of the country's foremost authorities on light metals, addressed a meeting of the CALIFORNIA BRANCH on April 5, on the subject, "Magnesium Alloys as Applied to the Messerschmitt 110 and Junker 88." While Professor Dorn, who for several years has headed a research project on magnesium alloys, was not in a position to divulge new developments in the United States usage of magnesium, he stressed the point that the engineering profession still has a tremendous task to perform to overcome the technological advancement of the Germans. A question period followed Professor Dorn's comments.

CARNEGIE TECH BRANCH held a short business meeting on February 22, for the purpose of electing new officers and to plan a program for the coming semester. The new officers are: Howard L. Engel, chairman; George G. Lail, Jr., vice-chairman, and A. Crawford McInnes, secretary and treasurer. This Branch met on March 14, when Thomas Purcell, general superintendent of power plants for the Duquesne Light Company, and former vice-president of the A.S.M.E., spoke on the problems facing the young engineer. Among other things, Mr. Purcell discussed the advantages involved in a professional organization for engineers, functioning similar to that of the doctors' Medical Association in maintaining professional standards.

Because of adverse weather conditions, COLORADO BRANCH was unable to hold the softball game with members of the A.I.C.E. on April 12, as previously scheduled. Instead, a short business meeting was held, after which members viewed the technicolor film, "Fortress in the Sky." After the film, Pi Tau Sigma, National Honorary Mechanical Fraternity, held pledging ceremonies.

At a joint meeting of the COLORADO STATE COLLEGE BRANCH and the A.I.E.E., on March 27, Professor Pennock gave an interesting account of his engineering experiences. At the April 10 meeting of the Branch, it was decided to postpone the election of officers until the next semester.

Jet Propulsion for Aircraft Features Kansas Meeting

Development and history of jet propulsion in aircraft were summarized by Prof. R. W. McCoy of the aeronautical engineering department, University of Kansas, at the April 6 meeting of the KANSAS BRANCH. Professor McCoy discussed in detail the principles and possibilities of jet propulsion and told of the numerous mechanical difficulties overcome before the Caproni-Camponi plane was built and placed in operation. He also told of some of the possibilities and limitations for future stratosphere flying. At the conclusion of Professor McCoy's remarks plans for the A.S.M.E. student convention were discussed.

An open discussion of the pamphlet, "The Second Mile," by William E. Wickenden, was held by members of the University of NEW HAMPSHIRE BRANCH on April 18, after which a lengthy discussion was held by the 17 members and guests in attendance. At this session, it was also decided to take a group picture at the next meeting of the Branch.

DR. ROBERT M. GATES WITH THE WINNERS OF THE STUDENT-PAPER CONTEST, GROUP III MEETING, APRIL 22, WITH COOPER UNION AS HOST

(*Left to right:* Stanley Handman, Polytechnic Institute of Brooklyn, *First Prize;* Carl Gans, New York University, *Second Prize;* Dr. Robert M. Gates, President, A.S.M.E.; Victor Cole, New York University, *Third Prize;* Jack Heller, Polytechnic Institute of Brooklyn, *Old Guard Prize.*)

A.S.M.E. STUDENT BRANCH, UNIVERSITY OF MICHIGAN, SPRING TERM 1944

Electronic Control Explained at City College, N. Y., Meeting

CITY COLLEGE BRANCH, New York, March 23 meeting was devoted to a lecture on "applications of the Electronik Potentiometer to Temperature Control," bv Mr. Orths and Mr. Tassi of the Brown Instrument Company. The lecture was high-spotted by an exhibition of the company's newly developed "Electronik Potentiometer," revealing the principles of the instrument in operation. While dismantling the instrument to show the arrangement of its constituent parts, the speakers clearly demonstrated how and why the electronic controller far excels any mechanical method. At the conclusion of the lecture, new officers were announced as follows: Ernest Chanes, president; Bernhard Lakritz, vice-president; Leon Feldman, secretary, and Jerry Smith, treasurer. The guest speaker at the March 30 meeting was Mr. Linsley, head of the public relations department of Wright Aeronautical Corporation, Paterson, N. J., who spoke on the production of engines at Wright plants. Mr. Linsley supplemented his talk with motion pictures, which depicted the entire process of engine production from the casting of cylinder heads to the final acceptance run on one of the company's many test blocks. Professor Kent of the mechanical-engineering department, also spoke on the subject of "The Draft and the Engineering Student." On April 6, the members enjoyed a film, through the courtesy of Mr. Linsley, on "Cyclone Combustion."

The first meeting of the NEW YORK UNIVERSITY BRANCH was held on April 20, at which members viewed a film entitled, "Steam Turbines." A brief discussion of the Student Convention at Cooper Union was then held, after which the meeting adjourned.

The April 10 meeting of the NEW YORK UNIVERSITY BRANCH (Day) was devoted to the presentation of student contest papers, the object being to determine who was to represent the college at the Student Conference on April 22. The first prize was won by Carl Gans, who spoke on the new field of "Biomechanics," and the second prize by Victor Cole, whose topic was, "The Design of a Jib Crane." The judges were Prof. Arthur C. Church and Prof. Ferdinand L. Singer of the mechanical-engineering and engineering-mechanics departments, respectively. This Branch held a short business meeting on April 12, at which questionnaires were distributed for the purpose of determining the best time to hold meetings, committee preferences, and the like, after which an election of officers was held. Officers elected to head the Branch are Hyman Appleton, chairman; Leonard S. Ganz, vice-chairman; Morton A. Burde-Bell, secretary, and Alvin Glover, treasurer.

Lieut. (j.g.) Paul Durup, U.S.N.R., recently returned South Pacific hero, was guest speaker at one of the most successful smokers ever held by NORTHEASTERN BRANCH on the evening of March 28. Lieutenant Durup, who is a graduate of Northeastern, class of '43, described the exciting adventures of a fighter pilot in the South Pacific to an enthusiastic audience of 83 members and guests. Prior to Lieutenant Durup's remarks, a representative of the Bethlehem Steel Company presented a colored film entitled, "Ships for Victory," which showed how a destroyer escort is built, via rapid war-production method.

A smoker was held by members of the OKLAHOMA BRANCH on February 17, at which time Professor Dawson explained the extreme importance and value of the A.S.M.E., and cordially invited nonmembers to join the Society. Two movies were then shown on "The Magic of Steam," and "Surface Condenser." Due to the fact that the membership of the Oklahoma Branch is limited, it was decided at the March 31 meeting to elect only a chairman and a secretary-treasurer. They are George C. Grogan, chairman, and John H. Moore, secretary-treasurer. The officers elected at the February 11 meeting were members of the Army Specialized Training Program, which program has been discontinued.

OKLAHOMA A.&M. BRANCH conducted an election at the March 27 meeting, the officers being as follows: Ray Kirk, chairman; Dick Pitcher, vice-chairman; Mary Eager, secretary, and Peggy Davis, treasurer. After the election, Professor Leonard explained the purpose and value of becoming members of the A.S.M.E. This Branch assembled on April 17, at which time Professor Leonard invited members ro attend a meeting of the A.S.M.E. to be held at Austin, Texas.

War Films Feature of Purdue University

Motion pictures entitled, "This Plastic Age," and "War Department Report," featured the March 29 meeting of Purdue Branch. From "This Plastic Age," a technicolor sound film, members learned about the development, production, and application of modern plastics to the war effort, as well as to prewar and postwar products. The second film, a report on the war effort, contained vivid scenes taken from U. S. Army Signal Corps films, depicting landing barges off Guadalcanal, jungle troops in New Guinea, and transport planes over the Himalayas in Asia, as well as several scenes from captured German and Japanese newsreels. On April 12, Dr. M. E. Mundel, of the general engineering department, spoke to the boys of this Branch on the subject, "Motion and Time Study for Victory." The word "victory" in this particular instance, Dr. Mundel explained, meant "victory" over laborious tasks by constantly devising ways and means to simplify the methods of their performance. His talk was illustrated by motion pictures. This Branch held a dinner meeting on April 19 at which G. Edward Pendray, assistant to the president of the Westinghouse Electric & Manufacturing Company, and president of the American Rocket Society, explained the theory of rocket flight and gave an interesting history of the experimental work that the American Rocket Society has done in rocket propulsion.

UNIVERSITY OF SOUTHERN CALIFORNIA on March 15 reported the formation of a bowling team, which was scheduled to meet its first opponent, the A.S.C.E. team, on March 31. It also reported that S. C. Allen was elected secretary, succeeding Mr. Moody, who resigned. An announcement was made at the March 22 meeting, that 17 new members had been added to the A.S.M.E., and a lengthy discussion of the merits of the Society followed the good news. Various committee heads were then appointed.

A.S.M.E. STUDENT BRANCH AT VIRGINIA POLYTECHNIC INSTITUTE

Members Jack Hart and Melvin Sturm of the TENNESSEE BRANCH on March 29 were selected to present papers at the student meeting, held in conjunction with the Spring Meeting of the A.S.M.E., Birmingham, Ala., April 3-5. Nominations of new officers for the summer quarter were also announced at the March 29 meeting, with decision to be reached by written ballot within two weeks' time. This Branch met again on April 12, to congratulate Melvin Sturm, who had won second place in the student competition with his paper on "Powder Metallurgy," at the A.S.M.E. Spring and Student Meetings.

Lieutenant Larson, formerly Aeronautical Engineering Student at the University of Utah, and recently returned from action in Kiska, addressed a meeting of the UTAH BRANCH on February 1, giving an interesting account of his experiences in the Aleutians against the Japanese. He then told of the outstanding job Army Engineers are doing in the construction of new roads under almost unbearable weather conditions. Touching briefly on aircraft construction, he told how planes are kept aloft despite a severe shortage of repairs parts, and in conclusion urged students to give serious consideration to the repair mechanic when designing aircraft. The first meeting of the Spring quarter of this Branch was held on March 21, at which members viewed three short films entitled, "A Wooden Yarn," "Thomas A. Edison," and "Excursions in Science—1." On April 18, three "Excursions in Science" films were enjoyed by the members.

Election of officers took place at the last meeting of the VILLANOVA BRANCH, with the following results: Chairman, Robert J. Casey, '44; vice-chairman, John Wilson, '45, and secretary-treasurer, John M. Millet, '45.

Virginia Polytech Members Enjoy A.S.M.E. Spring Meeting

Attendance of members of the Virginia Polytechnic Branch at the A.S.M.E. Convention held at Birmingham, Ala., April 3-5, 1944, has promoted a keener interest in the Society, according to G. R. Pucci, secretary of the Branch. He said the meetings were interesting and educational, and that a "swell" time was had by all.

Plans for a picnic supper at Black Hawk Lodge, and a contemplated "lawyer-engineer" dance were discussed by members of WISCONSIN BRANCH on March 15, but no definite decisions were reached. Arleigh Larson then gave a short report on his campaign activities, after which movies were shown and refreshments served. The advantages of being a member of the A.S.M.E. were high-spotted at the March 29 meeting of this Branch, after which several new members were added to the Society. Mr. Bassart of Milwaukee was the speaker of the evening.

A. S. M. E. Calendar

of Coming Meetings

June 5–9, 1944
A.S.M.E. Aviation Division Meeting
University of California
Los Angeles Campus
Los Angeles, Calif.

June 16–17, 1944
A.S.M.E. Applied Mechanics Division Meeting
Chicago, Ill.

June 19–22, 1944
A.S.M.E Semi-Annual Meeting
Pittsburgh, Pa.

October 2–5, 1944
A.S.M.E. Fall Meeting
Cincinnati, Ohio

October 23–24, 1944
Joint Meeting of A.S.M.E. Fuels and A.I.M.E. Coal Divisions, Charleston, West Va.

November 27–December 1, 1944
A.S.M.E. Annual Meeting
New York, N. Y.

(*For coming meetings of other organizations see page 46 of the advertising section of this issue*)

Registration in National Roster Urged

A FEW years ago members of The American Society of Mechanical Engineers had an opportunity to register with the National Roster of Scientific and Specialized Personnel in the War Manpower Commission, the agency of the Federal Government which, since 1940, has served as a central registry for persons possessing professional or scientific qualifications. All professionally qualified young engineers, chemists, physicists, geologists, mathematicians, etc., should be registered with the National Roster. If employers have personnel who possess the necessary qualifications and who have not yet registered with the Roster it is important to the war effort that they be asked to do so.

The Roster has been assigned the responsibility of obtaining the best utilization of professional and scientific personnel. The Roster maintains records of those of its registrants who are working in war industry as well as those who have gone into the armed forces, whether in an officer or enlisted capacity. In the light of recent Selective Service directives which will result in the induction of many thousands of professionally and scientifically qualified young men under the age of 26, it is important that these particular individuals who will enter the armed forces immediately notify the Roster of the branch of the armed forces they are entering, the date and place of their induction, and, after induction, their serial number. Obviously the Roster, as a civilian agency of Government, has no responsibility in the assignment of its registrants within the armed forces. At the request of the War and Navy Departments, the roster, however, does furnish advice to the Office of the Adjutant General, War Department, and the Bureau of Naval Personnel, Navy Department, concerning the specialized training and qualifications of those of its registrants who are inducted into the Army or Navy. This information is used as an aid in determining the initial military assignment of the particular individual.

It is conceivable that it may become imperative in the future—near or distant—to withdraw a number of professionally and scientifically qualified men from the armed forces in order to assign them to important research or production work in civilian war industry. The Roster's records are sufficiently detailed to permit intelligent selection of persons possessing professional qualifications in practically every kind of specialized field and it would probably be called upon to assist in any such assignment. It is important, therefore, that persons possessing professional or scientific qualifications register with the Roster and advise it immediately concerning any change in their status. Communications should be addressed to the National Roster of Scientific and Specialized Personnel, 1006 U Street, N. W., Washington 25, D. C.

Problems in Which Army Is Interested

Suggestions to Be Sent to National Inventors Council

IN the September, 1943, issue, page 692, was published a list of problems for which the United States Army wished suggested solutions. There has recently been received from The National Inventors Council, Department of Commerce, Washington 25, D. C., a second list of military problems which has been released by the War Department with the request that suggested solutions be sent by readers of MECHANICAL ENGINEERING to the National Inventors Council which will analyze them promptly and place those which appear novel and promising in the hands of appropriate military personnel. The list follows:

1 A relatively simple gage to measure the impulse of explosion blast, positive and negative phases to be determined separately but concurrently. It would be desirable if the duration of each phase could be determined in some simple manner.

2 A waterproofing compound for field application to nets. The compound must be susceptible of aqueous application. It must be colorless and not affect the flameproofing or infrared reflectance of the nets. It should add as little weight as possible to the fabric, should not seriously affect the "handle" (tackiness, flexibility, etc.) of the net fabrics, and should not adversely affect the tensile strength of the nets.

3 A lightweight material, other than Neoprene, Buna-S, or other similar rubber substitute now commonly used, which will hold air and CO_2. The material to be of noncritical materials and inexpensive.

4 A light detachable rock-drill-bit grinder for resharpening detachable bits. Capacity approximately 20 bits per hour and weighing 200 to 250 lb.

5 Removal of dissolved mineral matter from sea water and brackish water by ionic exchange process.

6 Means of controlling fires in fighting tanks for a sufficient period of time to evacuate personnel. The process should not be injurious to personnel and should be manually controlled and operated.

7 Waterproof compound for treatment of duck used in fabrication of canvas drinking-water storage tanks.

8 For field use, a simple, practical, and accurate method of determining moisture content of aviator's breathing oxygen.

9 A means for unloading ships by use of quickly erected tramway.

10 Means for increasing life of standard automotive or stationary engines when operated on 91-octane fuel.

11 The use of antistripping agents with cutback asphalts to permit effective coating of wet aggregates.

12 Additional methods for the chemical stabilization of soil.

13 A means for removing asphalt from drums and melting to pumpable temperature on a quantity production basis.

14 A quick and effective nonbituminous dust palliative for all climates.

15 Device to maintain or indicate, within 5 min, the relation of an aerial camera to the vertical.

16 Reduction of glare from glass surfaces by *durable* coatings suitable for field application.

17 Optical method for determining the difference between an artificial green and a natural green.

18 Destruction and removal of obstacles to landing operations. Obstacles may be visible or concealed and may be off or on shore.

19 Short-base, wide-angle range finder readily portable and capable of being mounted on a vehicle.

20 Location and destruction of concealed enemy emplacements, pillboxes, and similar strong points.

21 Methods of protecting our vehicles from the effects of enemy land mines.

22 Improvements in tank vision devices and control instruments. There is special interest in reducing space requirements and improving performance of gyroscopic compasses.

23 Ingenious and simple decoy devices for purpose of confusing and misleading enemy.

24 Technical data as to strategic enemy targets such as chemical plants, explosive plants, power plants, etc.

25 A voice-transmitting gas mask which would permit the wearer's voice to be heard with clarity.

26 Clothing giving protection against falling pieces of white phosphorus.

27 Colored smokes using readily available pigments for obtaining the desired color.

28 Protective ointments to counteract vesicants.

29 Methods of generating stable artificial fogs, and methods of dispersing artificial and natural fogs.

30 Protection against flame throwers.

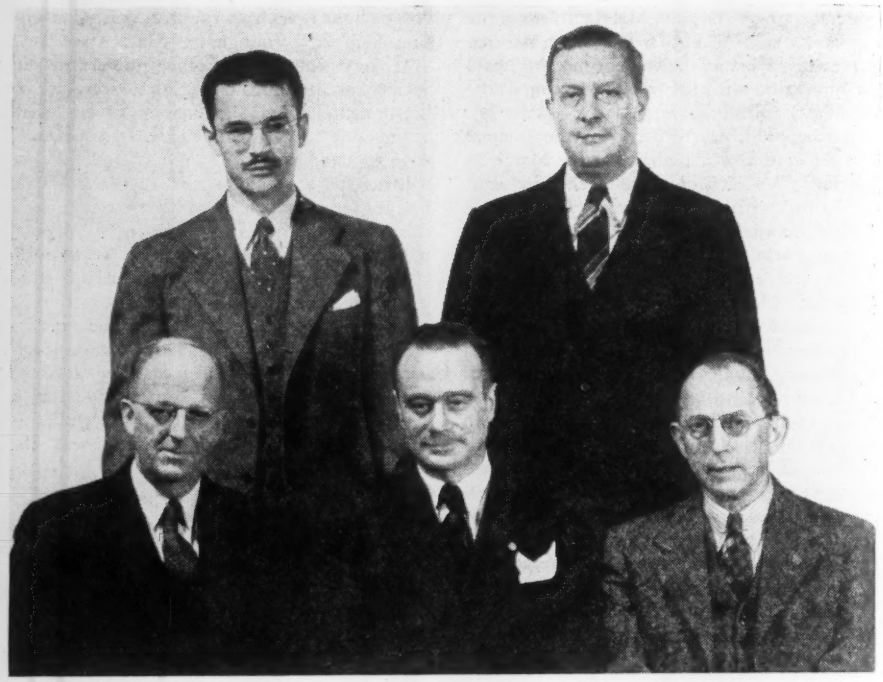
31 Odorless toxic agents.

32 Design of life vest which automatically inflates and turns the man on his back when he is thrown overboard by concussion and is unconscious.

33 *Noiseless* hand generator combined with a lightweight flashlight. The generator should be pumped at a rate of 40 revolutions per minute, and the light should be continuously brilliant and start on the first pump.

34 Plumb-bob type of generator to operate a light 6-volt radio. Generator probably operated by a reel winding up and letting out the plumb bob.

35 Methods of insuring CO_2 inflation of life rafts within 30 seconds time at temperature of —20 F to —40 F.



OFFICERS OF CHICAGO TECHNICAL SOCIETIES COUNCIL

(*Upper left*, Paul S. Smith, Institute of Radio Engineers, recording secretary. *Upper right*, K. H. Hobbie, American Society for Metals, corresponding secretary. *Lower left*, G. P. Halliwell, American Institute of Mining and Metallurgical Engineers, treasurer. *Lower center*, T. S. McEwan, The American Society of Mechanical Engineers, president. *Lower right*, B. E. Schaar, American Chemical Society, vice-president.)

Record 4000 Meet at C.T.S.C. Clinic

AT a record-breaking meeting, 4000 enthusiastic and interested engineers, scientists, and manufacturers gathered at the Hotel Sherman, March 30, for the Second War Production and Related Problems Conference sponsored by the Chicago Technical Societies Council.

The Clinic was again held at the request of the War Production Board and was in cooperation with the Board and the Army and Navy. A letter from Donald M. Nelson in part said, "The Council's forthcoming Conference on war production and related problems can make a genuine contribution to the war effort . . . Anything that your conference can do to bring about a greater volume of essential production will be genuine service."

The principal speakers were John Collyer, president of the B. F. Goodrich Company, and Rear Admiral A. S. Carpender, Ninth Naval District.

At the afternoon session, Mr. Collyer spoke on "America's Rubber Outlook," an illuminating and interesting talk on the development of synthetic rubber, facts on the present-day usage and performance and plans for tomorrow.

Rear Admiral Carpender paid high praise to the conference in the evening speech, in which he reviewed the course of the war in the Pacific by saying, ". . . We in the Navy look to the support which springs from a conference of this nature with a feeling of deep appreciation and profound gratitude . . . You would not be here if you did not realize that there is much to be done before we finally reach the day of unconditional surrender of our enemies."

Purpose of Conference

The purpose of the conference was to expedite the war effort by providing a means for the exchange of mutually beneficial ideas among engineering, technical, and scientific societies, and interested manufacturers in the Chicago area. The spirit of co-operation between manufacturing and technical staffs was ample evidence that a large group of people could get together and work for the common good.

The conference was held in a series of 33 panel sessions in which all phases of war production and related problems were discussed. All panel discussions were led by recognized experts in their fields.

Composed of the representatives of 36 societies, the aims of the Chicago Technical Societies Council are: (1) to provide a medium for co-operative action by the engineering, technical, and scientific societies in the Midwest on matters of mutual interest which are beyond the scope of individual societies or which can be performed better by co-operative action; (2) to provide means for more effective public service by the member societies; and (3) to cultivate greater appreciation by the public of the part which the engineering, technical, and scientific professions have contributed to human welfare.

Make-Up of Council

The Chicago Council is composed of two delegates from each member society including The American Society of Mechanical Engineers. Those desiring membership or further information should write to K. H. Hobbie, corresponding secretary, Chicago Technical Societies Council, in care of the Driver-Harris Company, 1140 West Washington Boulevard, Chicago 7, Ill.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York	Boston, Mass.	Chicago	Detroit	San Francisco
8 West 40th St.	4 Park St.	211 West Wacker Drive	100 Farnsworth Ave.	57 Post Street

MEN AVAILABLE[1]

ENGINEER, Purdue graduate, 35, B.S., E.E., 1935. Five years metal trader previous college. Parents American-born, Protestant, 7 years, present employer, now plant engineer. Desires $7500 manager, chief engineer. Me-842.

MECHANICAL-ELECTRICAL ENGINEER, M.S. Eighteen years' experience in machine shop, foundry, electric control, light and heavy manufacturing; desires permanent executive position in production or plant engineering. Draft: 2-B(H). Available now. Me-843.

MECHANICAL ENGINEER, 43, experienced in plant engineering, operation, surveys, cost estimates; substantial knowledge tool operations, welding, plate fabricating. Seeks responsible position production or plant engineering in heavy industry. Me-844.

GRADUATE MECHANICAL ENGINEER, 28, 4-F broad administrative and junior executive experience, especially in construction field; desire responsible sales or administrative staff position; some capital available; Los Angeles County. Me-845.

ENGINEER, 30 years' experience, instruments, controls, boilers, combustion, plant maintenance in design, layout, sales engineering, maintenance management. Married, 49, can go anywhere. Past three years war plant; interested postwar. Me-846.

POSITIONS AVAILABLE

SALES MANAGER, 40–50, experienced, graduate mechanical engineer with successful record as sales manager, to take charge of sales in laundry-machinery division. Substantial salary plus bonus. Illinois. W-3660C.

INDUSTRIAL BOILER AND POWER PLANT ENGINEER, under 45, capable of power-plant design and proper selection equipment and piping. About $6000 year. Pennsylvania. W-3667.

CHIEF ENGINEER, experienced mechanical engineer with extensive background in industrial management. Will have charge of drafting room, cost estimators, etc.; will be expected to advise on new equipment and proper layout of plant. Knowledge of treatment of brass and copper alloys will be helpful. One of major duties will be reconversion of plants to peacetime activities. Postwar opportunity. $12,000–$14,000, New England. W-3679.

ENGINEERS. (*a*) Industrial engineer with experience in shop processes and able to lay out complete schedule of machine operations. Some traveling. Headquarters, New York, N. Y. (*b*) Mechanical engineer, appraisal. Must have previous experience in appraisal on machinery, machine tools, and equipment. (*c*) Mechanical engineer with general management experience. Must thoroughly understand economics of an organization, sales structure, marketing and production, for an industrial management organization. Salaries open. New York, N. Y. W-3681.

CHIEF ENGINEER, graduate mechanical preferred. Must have experience and executive personality necessary to direct engineering design and development of all types of heat-transfer units, such as power plant, marine, chemical plant and refinery equipment. Permanent. $10,000–$15,000 year. New York, N. Y. W-3692.

CHIEF DESIGN ENGINEER, preferably experienced in design of high-speed special machinery similar to small printing presses. Should have considerable background of experience, be cost-minded and good executive type. $12,000–$15,000 year. New York, N. Y. W-3698.

PRODUCT DESIGNERS for streamlining company's product, particularly looking toward standardization of parts for postwar manufacture. Company has plants in Massachusetts and Ohio. About $5000 year. W-3717-B.

GENERAL SUPERINTENDENT, 38–44, mechanical-engineering graduate, capable of taking charge of plant employing about 1500 people. Processes involve ferrous and nonferrous molding, punch press, automatic screw machine, general machining, metal finishing and assembly. Comparatively small parts. Excellent postwar outlook. About $8000 year. Connecticut. W-3728.

GRADUATE MECHANICAL ENGINEER for development work in connection with small processing machinery, such as gun fire, control instruments, computers, stabilizers, etc. New York, N. Y. W-3738.

MECHANICAL ENGINEER, 35–45, for company manufacturing looms and spinning frames for textile industry. Should have thorough knowledge of machine tools, practical knowledge of tools, jigs, fixtures, etc. Experience in manufacture of textile machines preferred. Location, foreign. W-3761.

ENGINEERS. (*a*) Manufacturing engineers. Should be graduate mechanical with good substantial background in machine-shop practices. Will be required to estimate time and costs of operations, as well as fixtures and perishable tooling. Will be required also to lay out sequence of operations, specifying machines, tools, dies, jigs, fixtures, etc. (*b*) Development engineers with considerable experience in shop, to be required to work on specific customer problems and after studying existing methods, processes, procedures, etc., develop more efficient and superior methods. Must have imagination, ingenuity, and inventive talent. Should have well-rounded background and a sufficient knowledge of metal-working procedures—machine shop, foundry, forge, welding, etc. Will design product which has manufacturing ability. Location, Pennsylvania. W-3769.

ENGINEERS. (*a*) Chief engineer, experienced mechanical engineer for company with number of manufacturing plants over U. S. Excellent postwar prospects. $10,000–$12,000 a year. (*b*) Mechanical engineers for administrative work in tool or product design and/or industrial engineering for postwar work in various branches. $5400–$7200 a year. West. W-3776-S.

PRODUCTION AND MECHANICAL ENGINEER to take charge of plant in Mexico, making vegetable-fiber brushes. Able to handle Mexican labor. Salary open. Permanent. W-3779.

ENGINEERS. (*a*) Manufacturing manager, 35–45, graduate mechanical or equivalent, to be responsible for over-all control of flow of production through each plant from raw materials to finished products in accordance with a program planned to carry out production budget. Must be experienced in light metal-working, understand importance of processing and tooling, and have good background in production planning and control. Must be efficient, with good business judgment. (*b*) New products manager, 35–50, to report to the director of planning and control and be responsible for finding new products for the company to manufacture and market, and also act as liaison on new products with associated companies. Should have broad industrial background and be well acquainted with operating problems inherent in sales, engineering, and manufacturing. Should have experience required to analyze products and markets from standpoint of their volume and profit potentialities. Should have enough knowledge of engineering to know whether or not a product is well designed, to mentally convert drawings to working structures, to determine whether or not a product could be readily manufactured. New York metropolitan area. W-3783.

CHIEF ENGINEER in charge of design and development. Must have creative mind and ability to supervise drafting room. Experience in small machine parts, aircraft parts, electric irons, radio fittings, flexible tubes, desirable. $8000–$10,000. New Jersey. W-3789.

ENGINEERS. (*a*) Purchasing agent thoroughly familiar with the procurement of all materials, supplies, tools, and machinery used in the manufacture of safety valves, pressure and temperature gages, industrial instruments, electronic devices and instruments, aircraft instruments, steam specialties, etc. $6000 a year. (*b*) Engineer, co-ordinating executive

[1] All men listed hold some form of A.S.M.E. membership.